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Forthcoming Events.

SEPTEMBER 21-26.
Cycle and Motor Cycle Exhibition at Olympia, London.

SEPTEMBER 29.
Institute of Marine Engineers:—Ordinary meeting in London. "Recent Developments in Marine Propelling Machinery," Paper by Andrew I. Nicholson, B.Sc.

OCTOBER 2-5.
Smoke Abatement Conference at Buxton.

OCTOBER 2-17.
Textile Machinery and Accessories Exhibition at Manchester.

THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE
INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES EQUIPMENT AND SUPPLIES ASSOCIATION.

Institute of British Foundrymen.
PRESIDENT, 1925-26: John Cameron, Kirkintilloch, near Glasgow.
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General Secretary: W. G. Hollinworth, 38, Victoria Street, London, S.W.1.
Lancashire: T. Makemson, 21, Beresford Road, Gorse Hill, Stretford, Manchester.
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Welsh Engineers' and Founders' Association.
Secretary: F. J. Griffiths, 20, Fisher Street, Swansea.

Foundry Trades Equipment & Supplies Association.
Secretary: K. S. Bridges, Avenue Chambers, Southampton Row, London, W.C.1.

Indian Pig-Iron.

Of the British Dominions that have attempted to establish an iron and steel industry on modern lines in order to be less dependent upon outside sources, India in recent years has been the most successful from the point of view of increasing tonnage. It is, of course, true that, as in nearly all such enterprises, there have been anxious times, especially since the war. In many of the more highly-finished iron and steel products India was hopelessly beaten even in her home market. A formidable tariff wall now affords protection from the full force of foreign competition, though necessarily at the expense of the home consumer. Then there is the subsidy on steel production, only applicable, however, to Indian companies with rupee capital, of which the one important concern is the Tata Iron & Steel Company. In this respect the Bengal Iron Company and the Indian Iron & Steel Company, which have sterling capital, are at a serious disadvantage, faced as they are with the competition of a heavily subsidised concern owning five blast furnaces and a large steel plant, the output of which is being considerably increased. Whilst the present bounties—which were to have come to an end on September 30—have been slightly reduced for the additional period which will end in March, 1927, the annual maximum sum available has been increased to allow for a still larger output. In announcing the passing of the dividend on the £500,000 of preference shares, the directors of the Bengal Iron Company naturally protested against a system by which part of the taxation paid by the Company is handed over by the Indian Government to another company, thus helping them to carry on unfair competition.

The assistance, direct and indirect, being given to the Indian steel industry naturally has made a substantial difference in the volume of our export trade in iron and steel to that country; her total imports to-day are only about half what they were in pre-war days. On the other hand, as is well known, India is very favourably situated for the manufacture of pig-iron, and already she is developing a large export trade. During the first six months of the current year India exported no less than 208,647 tons of pig-iron, of which some 94,000 tons went to the United States, and over 71,000 tons to Japan; about 22,000 tons were imported into this country. In the first half of 1924 India's pig-iron exports were only 142,341 tons, and in the corresponding period of 1923 they amounted to 92,657 tons; this represents a very rapid increase, and apparently the tonnage exported is likely to grow considerably larger. Indian exports of pig-iron during the first half of this year were equal to 70 per cent. of our own exports of pig, including ferro.

With an abundance of excellent iron ore available, and for the time being of suitable coal, to say nothing of cheap labour, India can produce pig-iron at an extremely low cost, and the quantity she can dispose of appears more likely to be limited by the tonnage available for export than by her inability to undersell any competitor in foreign markets. In finished iron and steel the position, of course, is very different, and Indian manufacturers so far have been unable to dispose of their products anywhere but behind the tariff wall which has been erected for their protection.

Institute of British Foundrymen.

LONDON BRANCH.

The first meeting of the session was held last Thursday at the Engineers Club. The retiring president, Mr. V. C. Faulkner, occupied the chair. He congratulated the newly elected president, Mr. G. C. Pierce, upon his election, and assured him that he could rely upon the same whole-hearted support which he himself had received during his term. Owing to the fact that the annual meeting of the Institute would probably be held in London, there would be much hard work in front of the Branch, but he felt that the Council as at present constituted would accord the President a maximum amount of support. He then called upon the Branch President to deliver his Address upon what is wrong with the foundry industry.

PRESIDENTIAL ADDRESS.

What is Wrong with the Foundry Industry?

THE BRANCH PRESIDENT, after thanking the members for his election and reception, delivered his address, in course of which he said:—

GENTLEMEN: In presenting this address I would first like to make it clear that I am not attempting to persuade anybody that a *post mortem* is intended or meant. I wish to draw attention to one or two points as they appear to me as a practical foundry man, though it does not matter whether we get our living as practical foundry men or in any other connection with the foundry world. It is our livelihood, and it certainly behoves us to be ever watchful for circumstances that may injure our prospects, as a whole.

Everybody agrees that we are in anything but a happy position to-day from an economic, a technical or a practical point of view. Let us consider the economic aspect first. Here one can say but very little, because the constitution of the Institute precludes the discussion of questions of relationship between employer and employee, or Governments.

The Economic Aspect.

Bound up with economics as they effect the foundry, is the question of wages, hours and other contentious matters. However, a famous economist, who was expressing himself upon the state of an industry of which the foundry is part and parcel, stated that we, as a nation, could never again look forward to enjoying the position of being the premier engineering country of the world and all that that position entailed. Frankly, I cannot agree with him. I have a firm opinion that we shall, Phœnix-like, arise from the ashes and again establish ourselves. It is incumbent upon us if we are to "get back" to lose no opportunity of benefiting by past mistakes, and there have been some grievous mistakes made in the past which have left behind evils which if not tackled quickly, will grow into a canker that will be incurable. To use an "Irishism," *no progress* towards getting back can be made without first establishing a better relationship between employer and employee. Let there be no doubt, that the "feeling" that exists at the moment is one to be regretted. We are not in the position to blame either side, neither would it be wise to do so, but of this I am certain, there are troublesome times in front of us in the industry. We are going to be full of trouble if our present state of trade continues, and we are going to be full of trouble also if it improves.

This state of affairs, of course, is nothing new to foundrymen. On the one hand there is a cry for longer hours, and on the other there is demands for increased wages. Both of these are economic questions and are probably the most important of all, but, as such, they are outside our sphere.

There has been too much inclination, and there still is, to build everything upon what I term the wrong principle. Everybody in the name of business, or some other guise, has been seeking to get more than his proper share of the proceeds of industry and herein lies much of our trouble. Seriously, I believe, if everybody in the industry would "put himself in the other fellow's shoes" we should make real progress.

At the moment I do not think it opportune to consider the wider aspects of the economic side except to say that none of the arguments or facts brought forward by the pessimistic "Professor of Economics," or any that has been brought to my notice from other sources, is different from those brought forward in times of previous depressions. In 1906, the foundry industry, as a part of the engineering trade in general, was undergoing a severe trade depression. Some responsible people at the time were soon at work in endeavouring to persuade everybody that the end was coming, and if certain changes did not take place to keep in conformity with what was taking place in other parts of the world, no hope existed at all. Literature was forthcoming, advancing arguments, backed by figures that could easily prove their case, and yet the calamity never happened. We still struggled on, and in a short time were again back in the position that our pessimistic friends said could never be reached. If anyone cares to study industrial history they will find that the period which we are now passing through is merely a repetition of that which has occurred before and is mainly provoked by causes similar to those responsible for previous depressions in trade. It will be found also that the boom in the trade cycle will touch all and each of the countries concerned. At one time it will be America, then Germany, and so on and on. The movement may be quicker or slower, but it surely moves.

I do not advocate that anybody's condition must necessarily be made worse before anything can be done. Instead of upsetting the mental equilibrium of people with alarms, let us calmly tackle the issues from the standpoint of "What would I do if I were in the other fellow's position?"

The Technical Aspect.

It should be clearly understood that these comments are those of a practical man, and I would like it to be looked at as a request from one who has often been in difficulties in trying to come to a definite conclusion as to what has been done or what is meant to be done. I am referring now to the papers that are read at meetings of our own and other Associations, and also, of course, to various articles published in our Technical Journal.

I am, of course, assuming that those engaged purely upon the technical side are sincerely desirous of imparting their knowledge to all those who may be interested. If my idea is correct, then undoubtedly far too much language is used that is beyond the understanding of the greater number of men engaged in the industry. Unless simple terms and language are used, the efforts of those imparting their knowledge becomes wasted effort, because of this lack of understanding.

When one considers the statement that has been made to the effect that our craftsmen are made of boys and youths who have failed in every other trade at which they have been tried, one can easily see the necessity for the plea of simplification. Although I am seeking this simplification do not think that I agree that the statement as to source of supply of craftsmen is entirely correct. On the contrary, although there is some truth in it, I think it is greatly exaggerated. The craftsmen in the industry are second to none, and are worthy of a little condescension in this matter. If those engaged in the technical side can agree and practise the suggestion of more simplicity a real service will have been rendered to the industry.

Again, confusion often prevails as a result of the extreme differences arrived at by various people when dealing with the same subject, for instance, a certain non-ferrous metal upon which a great deal has been written and quite a good number of famous people have had something to say. The differences between them are astonishing and it makes one wonder whether some of them have been serious at times.

It is obvious that if one sets out to establish which is correct, much money must be spent by someone. The craftsman in the shop has no opportunity of investigating. The foreman also has but little opportunity. His department must be run upon a competitive basis as a rule, and

there can be next to no scope for experimenting in a competitive shop as it exists to-day. Unless the firm has a laboratory attached, very little hope exists of trying to establish some kind of proof as to who is right, and even then the question of putting into practice some conclusions has to be considered from the point of view of expense.

The practical man's only hope in this direction appears to be from such bodies as the British Cast Iron Research Association and the Non-Ferrous Research Association.

If these bodies can unify these varying opinions or results, they will have deserved their existence. I only hope that by some means, the findings upon subjects in which the practical man may have an interest will be made available for him. Just at the moment I think it is agreed that there is not much use in the practical man being associated with either body.

The Practical Aspect.

In any consideration of the practical side of the industry one must be struck by the progress made by other parts of the world as against that of our own. In this connection it is very interesting to note the remarks of Mr. Cole Estep, in the paper published in THE FOUNDRY TRADE JOURNAL on August 27. Mr. Estep, in his Paper, surveys the progress in the interchange of knowledge during the past few years and points out that generally the view of the British upon quantity production, as it is known in America, is that such methods of production must suffer from the point of view of quality. Mr. Cole Estep rather refutes this idea and endeavours to point out that by the scientific organisation necessitated in quantity production some guarantee is assured that the quality must be of a stable and sustained character. He also points out that without doubt the craftsmanship of the British moulder is without parallel anywhere in the world and offers as evidence that the cream of the artisans in America are those who have emigrated there. This to Mr. Estep, as an American, is good business, both from the point of view of obtaining good craftsmen and a first-class knowledge of their methods by the interchange that is occasioned by the development of the past few years of such Associations as the Institute of British Foundrymen, its American fellow, and those of France, Germany and Belgium. To be perfectly fair we must recognise that there is the return given of the knowledge gained by them in their papers presented as a *quid pro quo*.

Everybody, who has been connected with the foundries of this country for the past 20 years must admit that whilst technical knowledge has increased enormously and also the facilities to obtain that technical knowledge, the practical application of such knowledge is very much conspicuous by its absence. If we will not, or cannot, step in the same direction as our American, French, Belgian or German colleagues in applying the knowledge at our disposal, then it is our own funeral, and we must not mind when somebody else profits by our apathy.

Apart from one or two cases, the methods of production and the conditions existing now in foundries are no different from those of twenty years ago. Now this can only mean that either we do not know how to improve and have learnt nothing in 20 years, or we have gained knowledge and from a financial point of view are not in the position to apply it.

I emphatically refuse to believe that we have learnt nothing in the past decade or so. On the contrary, we have the evidence that other countries are anxious to exploit our knowledge and profit thereby.

Obviously either one or both of the other reasons given are applicable, and probably there is truth in both of them. No one connected with foundries is ignorant of the fact that the foundry of to-day is not the best paying proposition that one can find, and consequently the investing of new capital in order to keep pace with the development of industry is a very serious matter.

I have often pondered at the amount of damage done in the cutting of prices by the man who starts in a small way, probably entirely on his own, or perhaps with one or more partners who will work at their tools. Obviously, not much consideration is given to the question of keeping pace with the development of industry in such a business as this. There may be an expansion of business upon the old lines, but not with a view to being able to adopt modern methods. Unfortunately, one finds that these shops are of the type where the conditions and methods of production are the very worst that one can imagine, but despite all their drawbacks they deserve all praise for the initiative shown in striking out for themselves. It does seem, however, that the foundry section of the engineering industry is overburdened with the small man, who is able to quote prices, by virtue of his being free of charges which affect larger concerns, which are in themselves ridiculously low and cannot leave an adequate margin.

The curious point is, that generally these men are the best type of craftsmen in themselves and very proud of their craft as a craft, yet they do very serious damage to the industry by their methods of doing business. Sooner or later they reach a point where difficulties are met, and to keep their concerns together they take work and make it at prices that leave insufficient to meet expenses. An enormous amount of work is done by such concerns when considered from a point of view of tonnage, and this cannot fail to be a factor in keeping the market price of castings below that which is a proper competitive basis.

Foundries are Financially Starved.

There is prevalent the attitude shown by people having a great financial interest in foundries, who will authorise the expenditure of hundreds of pounds in other directions, but raise objections if the foundry asks for half a dozen new shovels. The only remedy for this feeling is to educate those responsible, in their early days, by ensuring that they have a real good training in the foundry in a practical manner It is very noticeable that those concerns which are administered by people with an actual knowledge of foundry practice, or those who are prepared to consider the foundry as an important department, progress upon the right lines. Even if they have no actual experience, but are prepared to recognise that the foundry is a place where brains and experience are necessary if it is to run upon modern and progressive lines.

It should be emphasised that a foundry cannot be expected, if men are worked under bad conditions, to develop the best type of man. It has been said that "Man was ever a product of his environment" and how very true that is we all know. Can it be wondered at when it comes to a question of placing boys into industry that those with knowledge of foundries take care that their sons are not going to be dependent upon such an occupation and work under such conditions as those as exist in a lot of our shops to-day. If we have the best to-day in craftsmanship, we must improve conditions or give up the position of first, to those of some of the countries who are keeping with the times. The argument that foundrymen themselves do not want these improved conditions, and where they have been introduced they have been abused, might have been true twenty years ago, but I dispute the fact of it being true to-day.

Complaints are often made that the best is not forthcoming from the men, and sometimes this is true. May I say here that as one who has had opportunity of studying this point and who comes into personal contact every day with them, that the greatest bugbear of their life is the fear of unemployment, and while it is not true to say a wilful withholding of production is in existence, it is true that if men could be assured that their employment is continuous, a greater zest would be shown in all that they do. It is not the shortest way, to quote economic facts about increased production making a guarantee against unemployment, to the foundryman. He will probably turn round and say that "Henry Ford," who knows all about production, has to discharge his men very often. Give him the assurance that his job will last and you will see a greater interest displayed. Let him know that his job hangs by a thread and his interest goes.

XUM

There has been a tendency on the part of the man in the shop to resent the introduction of machines and other labour-saving devices, and although this attitude is not yet dead, much of the opposition has died a natural death. These introductions, while increasing output, have, in my opinion, instead of lessening the number of skilled men required, had the reverse effect. If one inquires how many skilled men were engaged in the production of castings twenty years or so ago and compares it with the number who are available to-day in the same sphere, he will find that at least twice the number of fully skilled men are existing in Great Britain.

Co-operation Sought with the Designer.

I feel that I cannot conclude without adding just a little more to the old tale so often told, now that we have the Journal in which to express our views. I refer to the lack of consideration shown to the foundryman by the designer or draughtsman. This is another point where lack of practical knowledge of moulding enters in. We all know how often patterns come into the foundry with what the moulder terms "lumps and bumps" on. These projections in the greater number of cases, while they may be only very small in themselves as compared with the castings as a whole, cause as much time to be spent in conquering them as would be spent in making the whole casting. It does appear that jobs are designed without any regard at all for the foundry, and it too often happens that the draughtsman considers himself as being much too high in the engineering schedule to take notice of the foundryman. There are cases where happy co-operation takes place, and nothing but good comes from that co-operation. If those responsible for designing will more often consult the foundry a considerable amount of time, and consequently money, will be saved.

The Chairman proposed a vote of thanks to the President, which was seconded by Mr. W. B. Lake, who suggested that foundry owners should not have to pay carriage both ways on patterns: that experimental castings should be charged at cost price plus a percentage, and that a unified standard costing system should be nationally adopted. The resolution was supported by Major Small and Mr. H. O. Slater. It was enthusiastically carried, and in thanking his audience the President pleaded for increased membership and more regular attendance at the meetings.

I. B. F. Notes.

Presentation to Retiring London Branch President.

Last Thursday the Council of the London Branch offered a complimentary dinner to the retiring President, Mr. V. C. Faulkner. The function was held at the Engineers' Club, Coventry Street. Colonel W. F. Cheesewright, D.S.O., presided, and during the evening presented Mr. Faulkner with a silver cigarette box as a token of appreciation of his work for the Institute in general and the London Branch in particular. Supporting Colonel Cheesewright were Mr. G. C. Pierce (Branch-President), Mr. H. G. Sommerfield (Hon. Secretary), Mr. R. J. Shaw (Vice-President), Mr. W. B. Lake (Vice-President), Mr. A. R. Bartlett (Past President), Mr. H. O. Slater (Past President), Major F. Small, Mr. W. Ashwell, Mr. F. Cleaver, Mr. H. Shilitoe, Mr. A. F. Gibbs, Mr. J. W. Gardom, Mr H. E. Hand, and Mr. T. E. Fowler.

In making the presentation, Colonel Cheesewright made appreciative reference to Mr. Faulkner's work, first as secretary and then later for two years as President. That his work had been appreciated by the Institute as a whole was shown by the fact that Mr. Faulkner was now President-elect of the national body.

In reply, Mr. Faulkner stated that his work both in the Branch and on the general council had been a real pleasure to him. As Branch-President he had been particularly fortunate in having Mr. Sommerfield as secretary. He did not regard the function as valediction, as there was much more work for him to do in the future than he had ever done in the past. He sincerely thanked the Council for their kindness in arranging the function, presenting him with such an acceptable gift, and particularly for the support they had accorded him in the past.

Lancashire Junior Section Visit Stanton Works.

The Junior Section of the Lancashire Branch held their fourth works visit last Saturday, when some seventy members visited the works of the Stanton Ironworks Company, Limited, near Nottingham. The party was accompanied by Mr. R. W. Stubbs, President of the Junior Section, Mr. R. A. Miles, ex-President of the Lancashire Branch and manager of the Stanton Company's Manchester office, and Mr. T. Makemson, the Secretary of the Lancashire Branch.

The visitors left Manchester by the morning train and travelled in saloons to Derby, where they were met at the station by buses kindly provided by the Stanton Company. On arrival at the works the visitors were conducted round the plant by Mr. Taylor, the commercial manager; Mr. Grant, the manager of the spun pipe plant; Mr. Miles and other officials of the company. The plant for the manufacture of iron pipes by the centrifugal process was first visited; the visitors then passed on to the plant for the manufacture of concrete pipes. After lunch the blast furnaces were also visited.

The party was entertained to luncheon by the Stanton Company, and Mr. Fox, the managing director, who presided, welcomed the visitors in the name of the company. He also welcomed Professor Pisek, President of the Czecho-Slovakia Foundrymen's Association, who was present at the same time. The thanks of the party were voiced by Mr. Stubbs and Mr. Tom Makemson; Professor Pisek also spoke, and expressed his appreciation of the Stanton Company's plant.

New Section formed at Paisley.

The Scottish Branch have created a new section at Paisley. It is to be presided over by Mr. James Galt, of Sneddon Foundry, Paisley, whilst Mr. James Andrews, of Messrs. Fullerton, Hodgart & Barclay, Limited, Vulcan Works, Paisley, will act as hon. secretary.

New Branch Secretary Appointed.

Mr. S. W. Wise, of 183, Moorside Road, Eccleshill, Bradford, has replaced Mr. Love as honorary secretary of the West Riding of Yorkshire Branch of the Institute.

Aluminium Hollow-ware.

Manufacturers Apply for Import Duty.

The Board of Trade have appointed a Committee consisting of Mr. F. R. Davenport (Chairman), Professor A. W. Kirkaldy, M.A., B.Litt., and Mr. I. J. Hayward, to inquire into and report upon an application made by the British Aluminium Hollow-ware Manufacturers' Association, in accordance with the terms of the White Paper relating to Procedure and Inquiries in connection with the Safeguarding of Industries, presented to Parliament on February 3, 1925, for the imposition of a duty upon aluminium hollow-ware. The Secretary to the Committee is Mr. S. W. Hood, Board of Trade, Great George Street, London, S.W.1, to whom all communications relating to the work of the Committee should be addressed.

Czecho-Slovak Foundrymen's Association.

The third annual congress is to be held in Pilsen from September 25 to 28. Professor Pisek, who is at present in England, will preside. Papers are to be read by Monsieur Ronceray (Paris), Herr Mehrtens (Berlin), Monsieur Lemoine (Paris), Professor Ryska (Brno Technical College), Dr. K. Hejcman (Skoda Steel Works), Professors Glazunov and Mitinsky (Pribram Technical College), Dr. Czochralski (Frankfort), and Professor Hasa (Prague). The subjects to be dealt with include the following:—Foundry sands; cupola practice; wasters, heat and energy conservation in foundries; ingot moulds; apprenticeship, and shrinkage. The Skoda plant and the municipal brewery are to be visited.

THE IRON AND STEEL INSTITUTE.

AUTUMN MEETING AT BIRMINGHAM.

The Autumn Meeting of the Iron and Steel Institute was held at the University, Edmund Street, Birmingham, on Wednesday and Thursday of last week, the President, Sir Frederick Mills, Bart., occupying the chair.

Reception by the Lord Mayor of Birmingham.

In welcoming the members, the LORD MAYOR OF BIRMINGHAM (Alderman Percival Bower, J.P.) said it was peculiarly fitting that the Institute should come to Birmingham, for iron and steel had played a not unimportant part in the growth and prosperity of that city. Some of the finest machinery now being turned out in Great Britain had its origin in the district of which Birmingham was the centre. The result of scientific research and practical experience in great industries was to disclose all methods whereby industry could be assisted. It was because he felt the efforts of the Institute were directed towards that end that he welcomed the Institute, and trusted that the meeting would be an unqualified success.

THE PRESIDENT, on behalf of the members, thanked the Lord Mayor for the very cordial welcome he had extended to them to the city of Birmingham. Birmingham was certainly a very appropriate place in which to hold a meeting of the Iron and Steel Institute. It was the home of Dudley; of Andrew Yarrington (a name almost forgotten in the iron and steel trade, but that of a man who told people in the 17th century how to beat the Dutch without fighting, as would be found in an obscure little pamphlet in the Public Library, which was particularly interesting reading at the present time); of Bolton and of Watt. Nearly all the men who went to Shropshire and from there drifted into South Wales came from the Birmingham district, which was the home of the iron and steel industry as the world understood it to-day. It was therefore peculiarly appropriate that the members should visit Birmingham for the purpose of continuing their studies in the art.

The Dilatation of Cast Irons During Repeated Heating and Cooling.

By PROFESSOR J. H. ANDREW, D.Sc., and ROBERT HIGGINS, B.Sc., A.R.T.C. (Glasgow).

The work on the growth of cast irons by Outerbridge, Carpenter and Rugan, Campion and Donaldson, and Andrew and Hyman, was all carried out by repeatedly heating bars of iron to a predetermined temperature and measuring the change of volume on cooling after each successive treatment. This method gave a measure of the actual change in volume undergone by the specimens, but little or no indication of the mechanism of the reactions involved in such changes, even when supported by micro-examination. It was accordingly decided to extend the investigation of this troublesome phenomenon in another direction, and to determine the variations in length undergone during the process of heating and cooling.

The method used was successively to heat and cool small rods of the selected material 0.875 in. in dia. and 2 in. in length in the dilatation apparatus, as described by Andrew and his co-workers, the only difference in the apparatus now used being that a dilatometer of larger dimensions was employed. The flexible disc in the present form was 12 in. in dia. This increased diameter gave greater sensitivity, but it was found to be more troublesome to make perfectly watertight. This difficulty was overcome by the insertion of a thick rubber ring between the flexible disc and the body of the apparatus, the bolts being so adjusted as to bring about as far as possible an equal distribution of pressure over the whole area of the rubber ring. All glass and metal joints were cemented with a mixture of litharge and glycerine, and finally every joint, metallic or otherwise, was coated with a thick layer of varnish. Solid specimens with a small hole drilled for the insertion of a thermocouple were used throughout.

In the experiments of Andrew and Hyman, it was noticed that a large percentage of the increase in volume was due to the thick coating of oxide that formed over the surface of the specimens. Such a coating, if formed at the ends where the silica tube conveyed the expansion motion to the diaphragm, would greatly militate against the accuracy of the method. Accordingly, small discs of transparent quartz were inserted in between the specimen and the silica rods that butted up against it. This almost completely prevented even superficial oxidation of the ends. It was also noted that the specimen as a whole was only slightly scaled, the relatively enclosed space largely preventing this. In addition, each specimen was cleaned before each heat to remove the small amount of oxide formed.

The thermocouple, which was platinum—platinum-iridium, was connected with a sensitive mirror galvanometer through a Tinsley vernier potentiometer, which gave readings accurate to $\pm$ 0.2 deg. C. On account of the large number of irons chosen for the purpose of experiment it was decided to limit the number of heats to twenty-one, and only to take readings for alternate heatings and coolings. Micro-specimens in the form of cylinders, 0.75 in. in length and 0.875 in. in dia., were treated in exactly the same manner and at the same time as the dilatation specimens in another furnace. The maximum temperature for heating was the same in every case, namely, 900 deg. C. After attaining this temperature, soaking was allowed to proceed for three hours.

Preparation of Samples.

For the preparation of the cast irons the materials shown in Table I were used:—

TABLE I.

	C.	S.	P.	Si.	Mn.	Fe.	Al.
Ferro-manganese	6.50	0.01	0.25	0.75	78.0	—	—
Ferro-phosphorus	0.03	0.20	18.6	0.86	0.1	80.6	—
Ferro-silicon ..	0.09	0.03	0.04	48.7	0.8	50.0	0.5
Swedish pig-iron	4.20	trace	0.015	0.61	trace	—	—

The charges, of about 7,500 grammes in weight, were melted in a plumbago crucible by means of a Méker gas injection furnace; the Swedish pig was melted first, as rapidly as possible, after which the necessary additions were made. When completely melted all dross was skimmed off, and the metal poured through a small tun-dish into a hot sand mould measuring 14 in. deep by 2.5 in. in dia. A head of 3 in. dia. and of the same depth was allowed. The castings remained in the mould for twelve hours before stripping. Before machining to size 25 per cent. was cut from the top, and 5 per cent. from the bottom of the bar: this was discarded. Thus, specimens absolutely free from any chill effect were obtained.

TABLE II.

No.	Si.	Mn.	P.	G.C.	C.C.	T.C.	S.
2	1.52	0.036	0.029	2.45	1.9	4.35	0.013
3	1.51	0.971	0.025	2.00	2.43	4.43	0.009
4	1.40	2.090	0.019	1.59	2.57	4.16	0.010
5	1.30	3.140	0.030	1.22	2.87	4.09	0.009
6	1.45	4.120	Not estimated.				
7	1.41	5.450	Not estimated.				
P1	1.51	0.01	1.30	2.20	1.44	3.64	0.013
P2	1.53	0.016	2.04	2.00	1.53	3.53	0.016
P3	1.46	0.25	2.78	2.20	1.58	3.78	0.028
P4	1.40	0.28	4.20	2.50	0.84	3.34	0.013

In all, ten castings were made, the first series varying in manganese, and the second series varying in phosphorus. A silicon content of 1.5 per cent. was aimed at in order to represent as far as possible practical conditions. The analysis of the finished bars was as in Table II.

All the phosphorus specimens were machineable; of the manganese series Nos. 6 and 7 had to be ground to size.

Manganese Series.

The dilatation curves for each series have been plotted on Figs. 1 to 10, and they will be considered in their order of number.

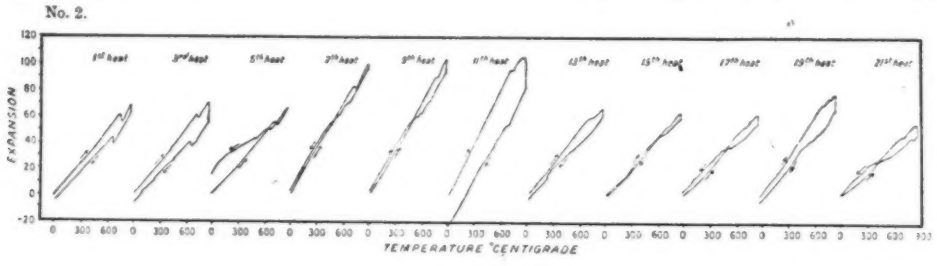


FIG. 1.

Iron No. 2.—A glance at these curves in Fig. 1 is sufficient to show the extremely intricate nature of the changes undergone by cast iron upon repeated heating and cooling to and from 900 deg. C. Not only is there a marked variation from one curve to another, but there is a decided periodicity with respect to the actual expansion undergone in each alternate treatment, as measured by the length of the vertical axis.

The first curve is normal, and indicates the usual contraction on heating and expansion on cooling at the critical point, which occurred at 800 deg. C. on heating and cooling respectively. It will also be noted that a small contraction occurred on soaking; this shrinkage, although but slight in the present case, was found to be very marked in certain instances. The contraction may be due to several causes—namely, (1) to partial solution of the graphite; (2) to oxidation of graphite causing porosity, which, under the conditions of the slight pressure to which the specimen was subjected, might bring about a compression; (3) to some change in the oxide material formed, either of a chemical nature or solution or deposition of the same; (4) to the evolution of gases. It cannot be due to graphitisation, which would cause an expansion. In the third heat there was a net contraction on cooling, and a large diminution in the size of the critical points both on heating and cooling. The fifth heat showed the first real evidence of graphitisation on cooling, marked by an appreciable expansion, which started at the critical point and persisted over a wide range of temperature.

At the seventh heat there was an abnormal expansion on heating. This may be due to either further graphitisation or to oxidation of the iron, due to the air percolating through the graphite flakes.

Since the greater part of the graphitisation had taken place by this time, it is probable that the latter cause predominated, although both reactions may be contributory causes. The ninth heat was similar to the seventh, and at the eleventh heat there was again a large expansion on heating. On soaking a marked contraction occurred, the final state on cooling being more contracted than before heating. Previous to the eleventh heat there were no signs of any pearlite in the iron, so that the increased expansion must be attributed to oxidation, which was found by Andrew and Hyman to precede decarburisation. The spaces occupied by the graphite originally would at this period of the treatment be filled with a mixture of iron oxide (FeO and Fe_3O_4) and graphite, the oxide surrounding the graphite. On soaking, the FeO would dissolve in the iron to a limited extent and diffuse through the mass, oxidising the particles of temper carbon present. The oxidation of the flaky graphite might or might not produce alteration in volume, but the oxidation of the temper carbon would cause a contraction due to carbon being replaced by finely divided iron, which would eventually become welded to and continuous with the mass. This reaction would take place according to the equation—

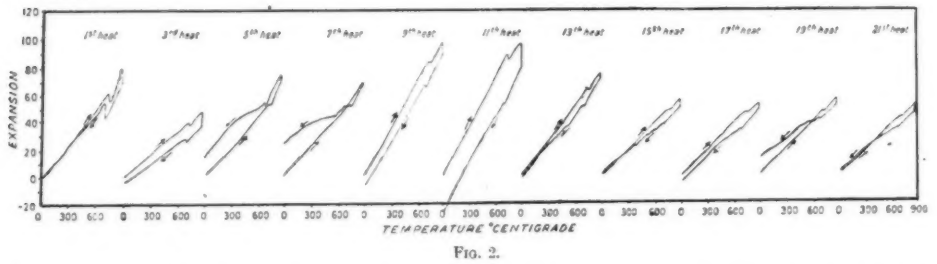


FIG. 2.

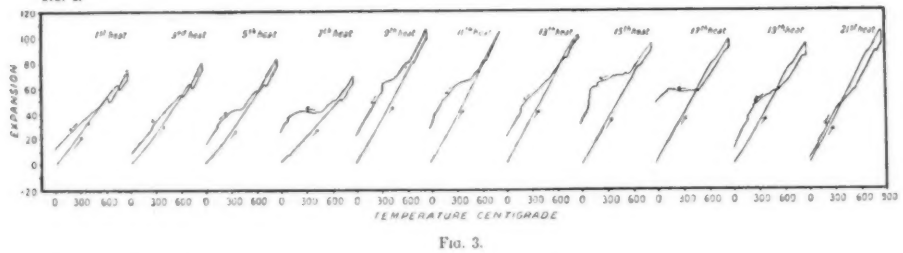


FIG. 3.

$$FeO + C = CO + Fe$$

with liberation of CO, which on account of the porosity of the material would be easily expelled.

After the eleventh heat there was an appreciable diminution in the coefficient of expansion. From the thirteenth to the nineteenth heat the curves must be regarded simply as dilatation curves of a highly oxidised iron.

The nineteenth curve is, however, of particular interest. The iron at this stage, being practically

devoid of carbon in any form, suddenly expanded on cooling, the expansion, which began at 720 deg. C., continuing over a wide range of temperature. This change must be due in some way to the oxide material; it may either be due to separation of oxide from solution, or to some reaction such as $Fe_3O_4 + Fe = 4FeO$, which is alleged by some to take place on cooling. Since, however, on analysis the separated oxide was found to be almost pure magnetic oxide, this suggestion is difficult to believe, and the most probable hypothesis is that excess oxide, of the nature of FeO, has dissolved to an appreciable extent on soaking at the high temperature, only to separate again on cooling. If this be correct, the contraction at 900 deg. C. on soaking must be attributed to solution of oxide. The dissolved oxide, it is assumed, would be in the nature of FeO rather than Fe_3O_4.

Iron No. 3.—This iron represents a fairly normal type, with about 1.0 per cent. of manganese. The curves for this specimen were of a similar type to No. 2 iron. The increased quantity of combined carbon is manifest in the first curve, the contraction on heating and expansion on cooling being greater than in No. 2. The marked contraction on soaking on the first heating could only have been brought about by resolution of graphite in the iron, and this was followed on cooling by a eutectoid change of considerable magnitude. In the fifth and seventh heats graphitisation would appear to have taken place both on heating and on cooling—indeed, from the micro appearance of the specimen at this juncture combined carbon was entirely absent. After the seventh heat all reactions are concerned with oxidation of the iron and elimination of free carbon. The very large expansion at the eleventh and thirteenth heats is significant of rapid oxidation of the iron on heating, and the contraction on soaking, of elimination of carbon by oxidation. By the nineteenth heat the carbon had almost disappeared, and on soaking the oxide was dissolved to a greater amount, only to be deposited on cooling, causing expansion. The twenty-first heat gave a normal curve for the highly oxidised material.

Iron No. 4.—On account of the considerable increase of the manganese content, resulting in an increased amount of free carbide, it was only to be expected that the progressive changes would be more pronounced, and extend over a large number of heatings and coolings. In the cast material large patches of cementite, presumably composed of manganese and iron carbides, were found on micro-examination. These patches gradually disappeared as the heatings progressed, but they did so individually and completely. In other words, when a cementite patch started to decompose the decomposition soon became complete: other patches, however, remained unaltered. For this reason repetition effects are noticeable features in the curves for the high-manganese cast irons. The large expansion on heating, which increased to the eleventh heat progressively, was again thought to be due to graphitisation, as was also the expansion on cooling beginning from the critical point. The reason for this repetition effect has already been commented upon, and was stated to be due to the decomposition occurring in patches. This interesting fact would seem to further substantiate the theory of Honda in that the oxygen of the air played an important part in the formation of graphite from cementite.

After the twenty-first heat most of the free carbon had disappeared and large flakes of oxide were present. Small patches of cementite were still visible, however.

The fact that the changes which occurred in the high-manganese series were in many cases associated with isolated patches, brings to light the possibility of having a number of different reactions all taking place at the same time, producing either similar or dissimilar effects in the nature of dilatation.

The smoothness of the heating curves was very marked, but the slight kinks on cooling must not be regarded as all representing definite changes, for in a heterogeneous mass, such as cast iron, slight changes are almost bound to take place at varying temperatures on cooling.

Iron No. 5.—The curves for this iron are of a similar nature to those of No. 4. As the manganese increased it was noted that the contraction on soaking became less. From the first heat it was evident that the greater part of the carbide

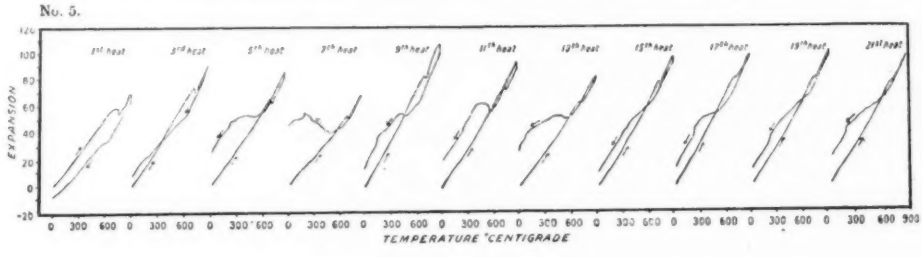


FIG. 4

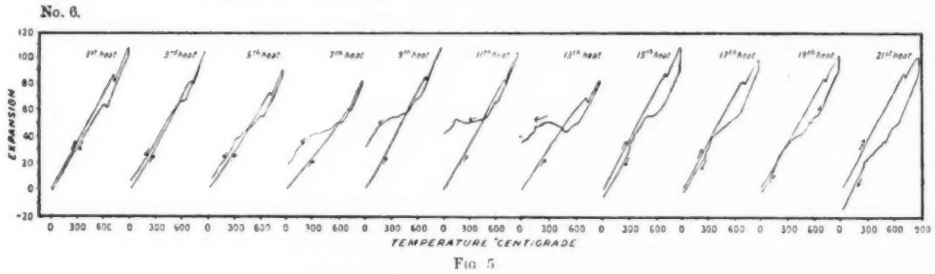


FIG. 5

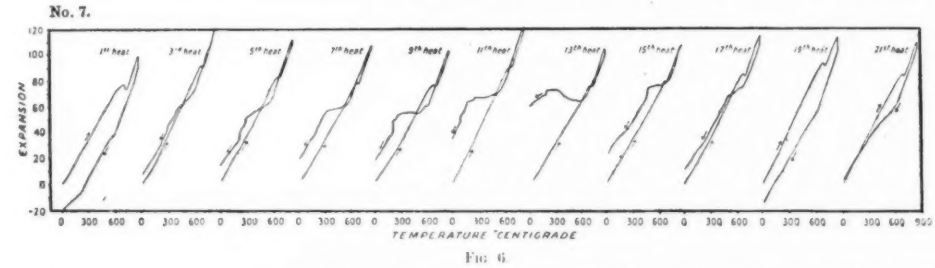


FIG. 6

was in the form of iron-manganese carbide, the pearlite carbide, judging by the magnitude of the critical point, being less than in No. 4. The extraordinary amount of graphitisation on cooling as seen in the curve for the seventh heat was a very marked feature of this series. It will be noted that when the heating curve showed a smaller ex-

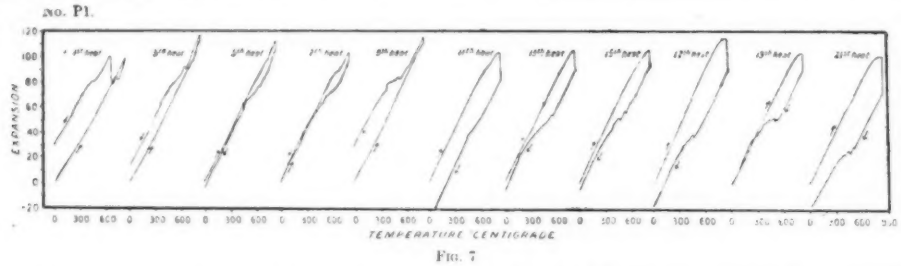


FIG. 7

pansion than usual, the expansion on cooling was greater. The absence of contraction on soaking might be attributed to the smaller solubility of manganese oxide, which must form, as compared with the iron oxide.

Although manganese is more readily oxidised than iron, it would appear that the manganese

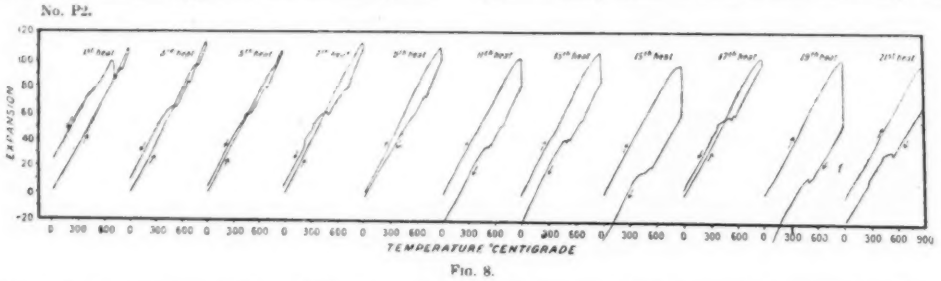


FIG. 8.

carbide is less so. Decomposition of Mn_3C can only give as products free manganese and carbon, both in the finely divided form. Manganese in this state of division would be expected to be easily oxidised. That this is so is apparent from the curves, which show an exceptionally large expan-

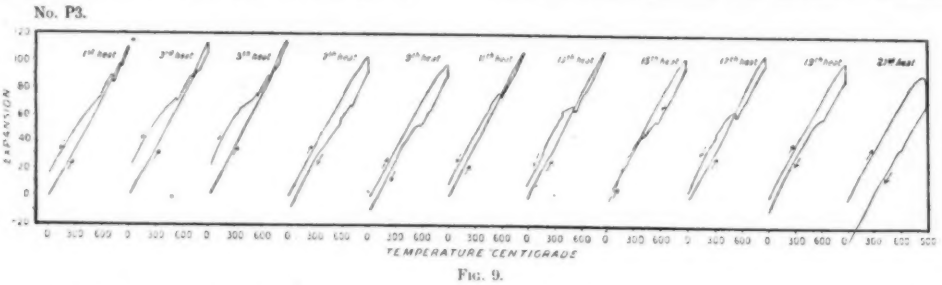


FIG. 9.

sion on heating at certain periods, as would undoubtedly result from oxidation of free manganese.

Irons Nos. 6 *and* 7.—Since irons Nos. 6 and 7 were fairly similar with respect to composition they

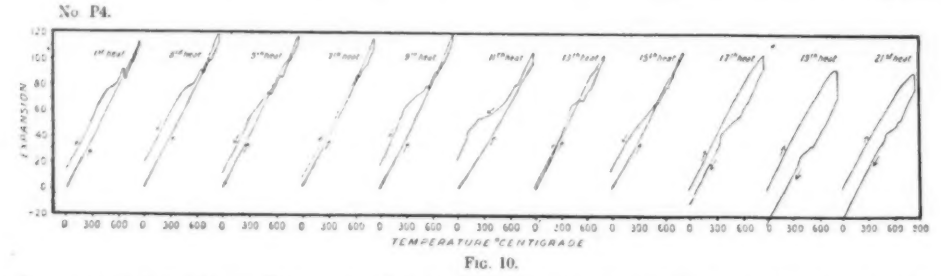


FIG. 10.

will be considered together. The most noticeable features were—the large expansion on heating, the complete absence of any definite critical point on cooling after the first few heats, and the fact of the greater number of heats being necessary to produce the large expansion due to graphitisation on cooling. The contraction on soaking noted towards the end curves of both series is difficult to explain, but when it is recalled that these two irons were of even a more patchy nature than the former ones, it is obvious that this contraction may be due to local action at certain particular parts of the material. It might be due to partial solution of the carbon, to partial solution of the oxide, or to any of the reasons previously mentioned. After the twenty-first heat both samples contained a considerable amount of free cementite, patches of free oxide in the form of flakes, and in certain places flakes of graphite.

Phosphorus Series.

The phosphorus series of irons presented many peculiarities, some of which are extremely difficult to explain. The total expansion in the phosphorus irons was considerably less than that of the manganese irons.

*Iron No. P*1.—The heating curve in the first heat showed a marked break at 800 deg. C., otherwise the expansion was normal. On cooling after this heat a very large expansion took place at 720 deg. C., the specimen at the completion of this expansion being of greater length than it was at 900 deg. C. No further change was noted on further cooling to ordinary temperature. After the seventh heat no change on heating was noted.

On cooling for the third time, the expansion at 720 deg. C. was considerably less, whilst in the fifth and seventh heats it was spread over a considerable range of temperature. The large expansion at the first heat, on cooling, was undoubtedly due to the almost complete

graphitisation of the free carbide of iron, as distinct from the carbide in the phospho-carbide eutectic, and it is seen that after the seventh heat this was completed.

On heating for the ninth time a slight expansion on soaking was recorded, and a large expansion on cooling; this has been assigned as being due to solution of the phosphide on soaking, liberating free carbide which, being surrounded by the phosphide, was protected. The carbide of the phosphide eutectic would go into solution in the iron, only to be deposited again on cooling in the form of graphite.

After the ninth heat a remarkable change is noted in the contour of the curves. Soaking at 900 deg. C. had brought about a very marked contraction. This contraction, which was obtained every time on soaking, was invariably followed by an expansion of varying magnitude, which began at about 520 deg. C. on cooling. The authors are only able to advance one reason for this relatively large contraction—namely, that it is due to phosphide of iron liquating and filling up the spaces previously occupied by the graphite. This explanation is supported by micro evidence. The expansion at 520 deg. C. is in all probability due to some change in the phosphide itself, possibly to the deposition of some substance which at the higher temperature was dissolved in it.

Iron No. P2 is of particular interest. The first heating and cooling curves are similar to P1, the expansion on cooling being less on account of a greater amount of the combined carbon being in the form of the phosphide carbide eutectic. Whilst the changes occurring in this sample are, generally speaking, similar to those of P1, the amount of contraction on soaking in the later heats was most abnormal.

Iron No. P3.—Cooling after the first heating brings about the usual expansion at 720 deg. C., smaller in magnitude than in any of the previous samples on account of an increase in the amount

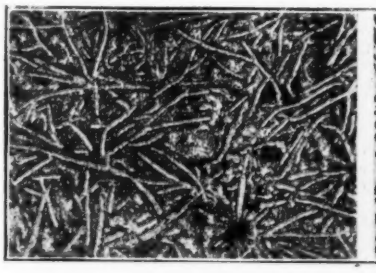


FIG. 15.
No. 3. 20th heat. Etched. ×75.

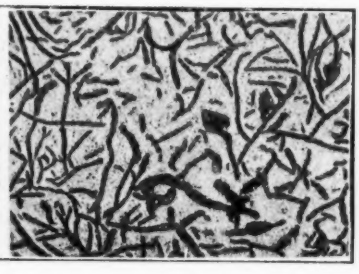


FIG. 16.
No. 3. 20th heat. Unetched. ×75

FIG. 17.
No. 6. 4th heat. Etched. ×75.

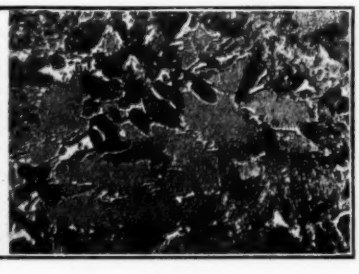


FIG. 18.
No. 7. 8th heat. Etched. ×75.

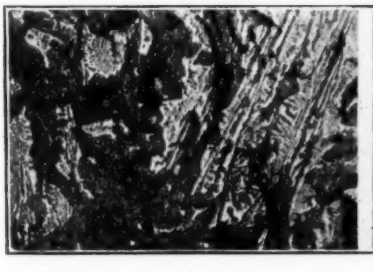


FIG. 19.
No. 7. 11th heat. W.Q. 900 deg. C.
Before soaking. Etched. ×75.

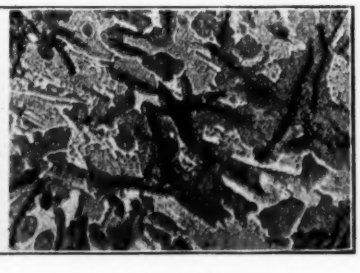


FIG. 20.
No. 7. 11th heat. W.Q. 900 deg. C.
After soaking. Etched. ×75.

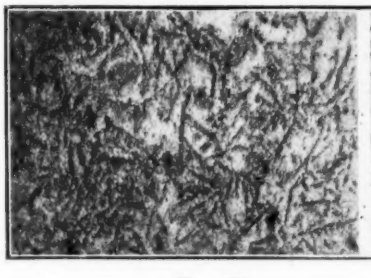


FIG. 21.
No. 2. 11th heat. W.Q. 900 deg. C.
Before soaking. Etched. ×75.

FIG. 22.
No. 2. 11th heat. W.Q. 900 deg. C.
After soaking. Etched. ×75.

of the phospho-carbide eutectic. All critical points on heating disappear after the fifth heat, whilst the cooling curves indicate a marked transformation at about 520 deg. C., due, as has been suggested, to a change in the phosphide constituent. The contraction on soaking in the later heats is far less marked than with either No. P1 or P2.

Iron No. P4.—The main feature with regard to this iron lies in the small expansion that persists on soaking, up to the eleventh heat. This, along with the fact that on cooling the change point at about 720 deg. C. was distinct even after the fifteenth heat, further supports the contention that soaking has produced the liberation of the iron carbide from the phosphide eutectic and its solution in the iron. The marked contraction on soaking was found only towards the end numbers of heats.

The reason why the contraction effect is delayed by the high phosphorus content is thought to be due to the slower oxidation of the graphite delaying the formation of voids into which the phosphorus would liquate. Until the graphite has been completely oxidised out the maximum contraction would not be observed.

Microstructure.

Micrographs Figs. 15 (etched) and 16 (unetched) are typical of a completely oxidised specimen.

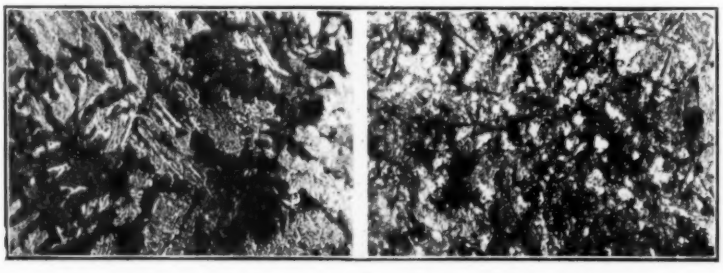


FIG. 23.
No. 5. 7th heat. W.Q. 800 deg. C. After soaking 3 hrs. at 900 deg. C. Etched. ×75.

FIG. 24.
No. 5. 7th heat. Slowly cooled. After soaking 3 hrs. at 900 deg. C. Etched. ×75.

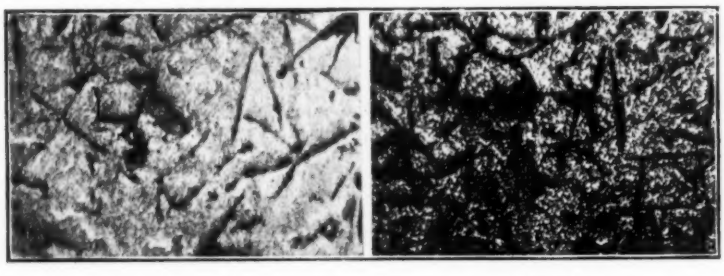


FIG. 25.
No. P1. 1st heat. W.Q. 800 deg. C. After soaking 3 hrs. at 900 deg. C. Etched. ×75.

FIG. 26.
No. P1. 1st heat. W.Q. 400 deg. C. After soaking 3 hrs. at 900 deg. C. Etched. ×75.

FIG. 27.
No. P2. 21st heat. Etched. ×75.

FIG. 28.
No. P4. 21st heat. Etched. ×75.

FIG. 29.
No. P4. 21st heat. Unetched. ×75.

FIG. 30.
No. P3. 16th heat. Unetched. ×75.

The oxide material is seen to fill completely the spaces originally occupied by the graphite, whilst small particles of oxide are disseminated through the mass. The larger masses in certain cases had the appearance of mixed oxides.

It was quite usual to find in the manganese series isolated patches, in which complete oxidation had taken place early with respect to the

number of heats. Fig. 17 shows one of these patches found in iron No. 6 after the fourth heat; it also shows the breakdown in grain-size due to the rapid diffusion that must have occurred in the production of this structure. Patchiness of structure is again illustrated in Fig. 18, which shows a patch of undecomposed material in iron No. 7 after the eighth heat. The massive cementite and pearlite are clearly evident.

Figs. 19 and 20 are of iron No. 7, the eleventh heat. Fig. 19 is the structure of a sample as quenched on attaining 900 deg. C., whilst Fig. 20 is of the same iron at the same heat as quenched after soaking at 900 deg. C. for three hours. The difference between these two structures is that in Fig. 19 the graphite flakes are unchanged, whilst in Fig. 20 they are intermingled with oxide material. From the dilatation curves it will be seen that this iron, on soaking at 900 deg. C. during the eleventh heat, underwent a marked contraction. This micro is further confirmation of the suggestion made that the contraction was due to the small particles of oxide dispersed throughout the iron diffusing and coalescing in the spaces occupied or left by the graphite. This diffusion effect is more clearly

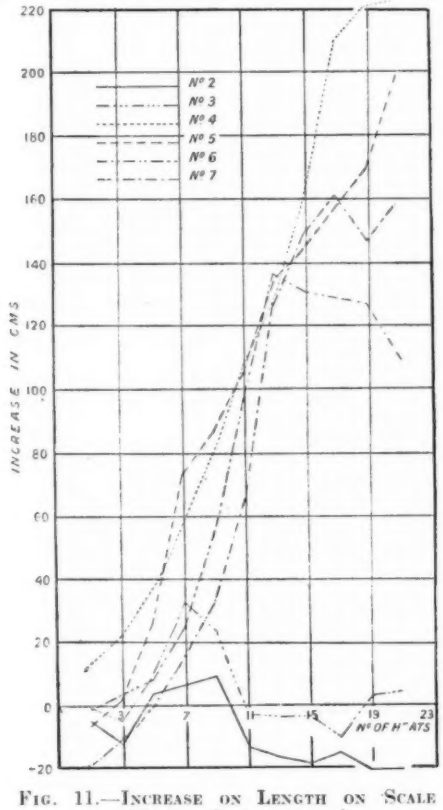


FIG. 11.—INCREASE ON LENGTH ON SCALE AT 15 DEG. C. (SUMMATED).

seen from Figs. 21 and 22. No. 2 iron, eleventh heat. Both have been quenched from 900 deg. C., but the specimen shown in Fig. 22 was soaked at 900 deg. C. for three hours, whilst that in Fig. 21 was allowed to attain that temperature and immediately quenched. The extreme fuzziness, due to small particles of oxide seen in Fig. 21, has been almost completely cleared by the soaking treatment. The large expansion which took place in iron No. 5 at the seventh heat on cooling is clearly explained by micros Figs. 23 and 24. Fig. 23 shows the structure after quenching from 800 deg. C. following upon soaking at 900 deg. C. for three hours, and Fig. 24 that of the same iron at the same heat as soaked at 900 deg. C., but allowed to cool slowly to ordinary temperature. The graphitisation of the carbide is quite evident.

Fig. 25 shows the structure of P1 as quenched from above the critical point on cooling. The specimen had not been previously heated. The structure is seen to consist of martensite and graphite. As illustrating the graphitisation on cooling slowly through the critical point, Fig. 26 shows the same iron also heated for the first time, but allowed to cool to 400 deg. C. before quenching. The increase in the amount of graphite and absence of pearlite is very apparent. Fig. 27 depicts the structure of P2 after the twenty-first heat (etched). The large flakes have every appearance of being composed of FeO and phosphide. Fig. 28 is of P4 after the twenty-first heat, but in the etched state. The blackness of the flakes suggests that a certain amount of graphite is mixed with the phosphide as well as some FeO. The same structure unetched is shown in Fig. 29, in which the phosphide is easily discernible. Fig. 30 illustrates very well a stage in the process of liquation of the phosphide. This structure, which was unetched, shows flakes of oxide and phosphide, in which the two constituents are in places distinct and separated.

During the period in which rapid solution of phosphorus took place small grains of exactly the same pattern as shown in Fig. 17 were always observed.

Discussion of Experimental Results.

A remarkable feature common to all the dilatation curves lies in the diminutive size of the true critical points, as distinct from the larger

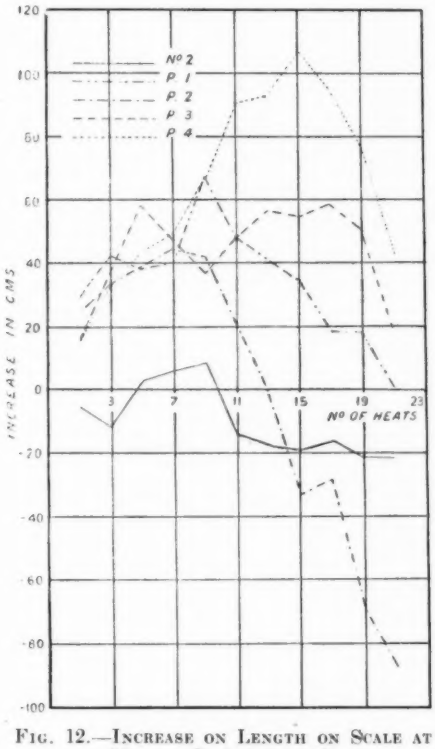


FIG. 12.—INCREASE ON LENGTH ON SCALE AT 15 DEG. C. (SUMMATED).

changes due to graphitisation. After a relatively small number of heats it becomes increasingly difficult to determine exactly what may be styled as a critical change in distinction to the small, sudden variations in length, brought about most probably by local reactions within the specimen. In view of the constancy of certain deflections throughout every series, it is possible to distinguish the real from the apparent, and to state quite definitely that in all the irons experimented with only one true critical point on heating, and one on cooling, pertained. In the manganese series the variation in temperature as the manganese increased amounted to at the most 50 deg. C.

From the work of Charpy and Thenard, and of Honda and Murakami, it would seem that a silicon content of 1.5 per cent. is sufficient to obliterate all critical points in a pure iron excepting the magnetic or A2 change, whilst the work of Hanson and Colbeck would appear to show that manganese when added to an iron-silicon alloy

has but little effect, silicon being the predominating element.

The single critical point observed on heating and on cooling in all the irons must then be the A2 change, unaffected by manganese, excepting in the initial stages, where pearlite forms on cooling. The absence of any A3 or A1 change naturally implies that on heating to 900 deg. C. the iron never becomes transformed into the γ state, and this conception receives considerable support from the experimental data.

No pearlite was detected in any of the samples after they had been heated for a second time to 900 deg. C., usually one heating was sufficient to completely graphitise all the carbide originally existing as pearlite. Free cementite, and in the phosphorus series large patches of the phospho-carbide eutectic, were clearly visible on micro-examination.

It is suggested that the following reactions take place on cooling an iron containing 1.5 per cent. of silicon from the melt:—Immediately after freezing the alloy will consist of free cementite and silico-austenite. On further cooling, graphitisation will take place according to the stable iron-carbon diagram, until the eutectoid point is reached, when pearlite will form. Any free manganese-iron carbide, or free phosphide-carbide eutectic, will remain as such throughout the cooling.

Upon heating again, assuming the iron to remain in the α state to the upper limit of temperature under consideration, viz. 900 deg. C., iron carbide would gradually go into solution in the α-iron, the solubility increasing with temperature. Simultaneously with solution there

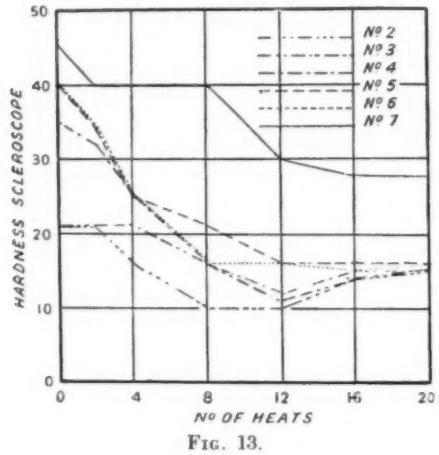


FIG. 13.

would occur graphitisation, which would take place progressively on heating up to 900 deg. C. Upon cooling again no change would occur until the A2 point was reached, which, whilst it cannot perhaps be regarded as an allotropic change, must be in the nature of a change in the atomic or electronic configuration, and is apparently sufficient to bring about a complete breakdown of the dissolved carbide and free carbide of iron, with the formation of graphite. That masses even of manganese-iron-carbide break down completely under these conditions is evident from a micro-examination of a specimen quenched previous to and after the critical change. The experimental evidence points to some solubility of silicon in both the carbide of iron and double carbides of iron and manganese, also to the fact that the presence of finely divided or temper carbon rapidly initiates their breakdown. In the phosphorus series, graphitisation in iron P1 was even more complete at the critical point, which in the first cooling curve is seen to give rise to a relatively enormous expansion. Phosphorus in solution has evidently a "salting-out" effect, incidentally causing an apparent increase in the silicon content, thus increasing the activity of that element with respect to its graphitisation propensities. The phospho-carbide constituent would seem, however, to be a relatively stable body unaffected by silicon. This is to be expected when it is considered that this eutectic freezes at a temperature considerably below that at which all the silicon has become solid, and on this account will be free from the graphitising element.

Graphitisation does not, however, serve to explain all the reactions involved in the growth of cast iron; oxidation of the iron plays an almost greater part in the actual increase in volume. At the temperatures concerned, oxygen has a greater affinity for iron than for carbon, and it was always found that it was not until a considerable amount of Fe_3O_4 was formed that decarburisation proceeded with any avidity. In immediate contact with the unchanged iron there would undoubtedly be the lower oxide (FeO), which at the higher temperatures would diffuse to a limited extent into the metal and oxidise the small particles of temper carbon previously formed, giving rise to a further change in volume and to the formation of carbonaceous gas. Whether the gases thus formed are responsible for any increase in volume is doubtful, as their evolution from the iron would be aided by the porous nature of that material. Solution of ferrous oxide would be expected to give an increase in volume. Further, in the phosphorus series, solution of the phosphide would follow into graphitisation, this latter reaction, producing a carbonless silico-ferrite, would cause an expansion. Diffusion of the phosphide would, by depriving the carbide of the phospho-carbide eutectic of its protective action, immediately bring about the graphitisation of that carbide, on cooling.

Contraction would be brought about by the following reactions:—

(1) By deposition of oxide of iron in solution, there would be a tendency for this oxide to diffuse towards the massive oxide segregates, which filled the spaces originally occupied by the graphite, and to be deposited on them.

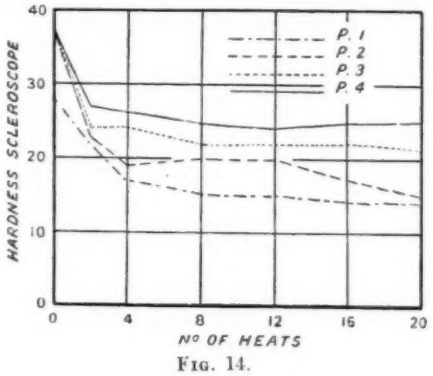


FIG. 14.

(2) By liquation of the phosphide material. It was found that the phosphide showed a marked tendency to diffuse into and partially fill the hollow spaces formed on oxidation of the graphite, and also into the porous graphite itself.

(3) By oxidation of the carbon, either in the form of graphite or in the combined state. Oxidation of the graphite would create voids, and it is possible that the specimens being under slight compression might tend to contract. Oxidation of the combined carbon would bring about an immediate contraction.

It was only to be expected that the centre of the specimens was less oxidised than the outside portions and the metal adjacent to the outside. This non-uniformity made a true chemical analysis impossible, since the zones were so widely different and the lines of demarcation abrupt. Analysis did show, however, that with the phosphorus series complete decarburisation had not taken place by the end of the twenty-first heat, excepting in the case of P1. Phosphorus would be expected materially to affect the iron with respect to oxidation, serving, when in solution in the iron, to protect it appreciably. Indeed, it was found that the higher the phosphorus content of the metal the less became the amount of that constituent which could be definitely termed oxide, and in the later numbers the structure, as determined by the microscope, revealed a constituent which had all the appearances of mixed

phosphide and graphite. Reasoning on this basis, the large contraction on soaking obtained in P2 may be attributed to the more or less complete oxidation of the carbon directly by the air and the filling up of the spaces by phosphide material. In the high-phosphorus samples, however, liquation of the phosphide would be expected to take place more readily, producing two effects—namely, the freeing of iron carbide, which on decomposition would bring about an expansion; and, secondly, liquation of the phosphide into the graphitic material itself, thus partially protecting it from rapid oxidation. Phosphorus would appear to have a delaying action, but in every case would eventually produce a contraction.

Manganese, whilst it has a stabilising effect on the carbide, makes the iron more prone to oxidation, whilst the product of decomposition of manganese carbide, namely, manganese and carbon, would be most readily oxidised. That this was the case was evident from the rapidity with which the manganese iron carbide, once it had decomposed, became oxidised.

In Figs. 11 and 12 there are plotted the growth figures, measured in terms of the dilatometer (34 centimetres are equal to an actual expansion of 0.01 of an inch on 2 in.). In the manganese series (Fig. 11), it is seen that in every case the expansion which takes place in the preliminary heatings shows a tendency to cease after a certain number of heats and become a contraction. There is no relation between chemical composition and growth shown by these curves—growth is, however, dependent upon so many factors that in a heterogeneous material, such as cast iron, it is not to be expected. Growth must, for instance, be dependent upon the amount of graphite, upon the volume and size of the graphite flakes, upon the form of combination of the manganese, and other variable factors. Similar curves are shown for the phosphorus series (Fig. 12). The remarkable position of the curve for P2 relative to the others is inexplicable. The curves do, however, point to the delaying action of the phosphorus, for, with the exception of P2, the higher the phosphorus content the greater the number of heats are required to produce the same amount of contraction. Here, again, the rate of the reactions will depend upon the size and configuration of the graphite flakes, and upon the position and form taken up by the phosphorus with respect to the other constituents. An important conclusion of this work with respect to the choice of suitable materials to withstand heat is that if cast iron be selected it is imperative that the silicon content be low—a conclusion come to by Carpenter and others from practical tests. The addition of a carbide-forming element, whilst it would serve to stabilise the carbide, would in no way assist in preventing decomposition of the pearlite, silicon having the effect of immediately bringing about the graphitisation of carbide in solution the moment it tended to be deposited from solution in any form.

The scleroscope hardness of all the specimens taken after the different heats are given in Figs. 13 and 14.

The Davis Steel Wheel and Its Manufacture in England.

By W. R. MARTIN (Chicago, U.S.A.).

(*Abridged.*)

Briefly, there are to-day four general types of wheels in use in modern railway practice. They are: the steel-tyred wheel, comprising a tyre mounted on a centre; the chilled-iron wheel; the solid rolled steel wheel, in which the centre and tyre are rolled in one piece of the same material and of the same physical characteristics; and the Davis steel wheel. The steel-tyred wheel has many variations in the nature of the centre used, the fundamental idea being to employ a soft material, such as wrought iron or cast or rolled mild steel. In America, the use of the steel-tyred wheel under passenger cars was begun about 1870. This wheel has now largely been replaced by the Davis steel wheel and the rolled steel wheel.

The author has the privilege of bringing before the Institute an interesting development in this country in the form of the manufacture of the Davis steel wheel. He has been in England for some time acting in an advisory capacity to the firm of John Brown & Company, Limited, and this firm have now put into operation a new plant specially laid down at their Scunthorpe Works for the production of these wheels. Hitherto the Davis wheel had been exclusively manufactured by the American Steel Foundries, at their Granite City plant, U.S.A., since its inception and development by its inventor, Mr. J. C. Davis.

About twenty-five years ago there were practically only two kinds of car wheels in use by the railways in America—*i.e.*, the steel-tyred wheel and the chilled-iron wheel. Already at that time a general tendency towards heavier weights of rolling stock, greater capacities, together with higher speeds, had become evident. About this time Mr. J. C. Davis, of the American Steel Foundries, recognising the limitations of the physical characteristics of cast iron, even when of the best quality, conceived an entirely new type of steel car wheel. He pictured as the most desirable development a one-piece wheel which would integrally combine a hard-wearing tread or tyre with a soft and ductile centre, thereby eliminating the two-piece construction of the steel-tyred wheel. The safety advantage of a one-piece wheel is self-evident, especially where much braking is employed. His ultimate development was the Davis steel wheel as it is known to-day, with its soft and safe plate and boss, and its long-wearing tread of water-toughened manganese steel.

However, the chilled-iron wheel embodies one basically valuable principle. It is essentially based on the time-honoured one-wear idea—that is to

FIG. 1.

say, with this wheel there is no periodic withdrawing of the wheel from service for reconditioning of the tread. It runs its full life on one wear, and without any necessity for removal from service. Mr. Davis envisaged such a principle in steel, and how well he foresaw the needs of the future has been demonstrated in the years that have followed. He planned a tread metal of such composition and physical characteristics for resistance to abrasion that a one-wear mileage could be obtained equal to the full mileage of a heavy steel tyre, including the several reconditioning operations of the latter, thus offering the railways a wheel with many times the life of the chilled-iron wheel, yet with none of the maintenance work and expense necessary with the tyred type of steel wheel. Hitherto tyre-turning had always been accepted as a necessary and constantly recurring operation in connection with the use of steel wheels. Its elimination means an important saving, and far-reaching convenience in railway operation.

In order to achieve in a one-piece structure a differential composition in the tyre as compared with the centre portion of the wheel, centrifugal casting was employed. Obviously the pouring gate had to be at the centre, and so arranged as to permit the higher composition metal first entering the mould to be carried out to the tyre portion of the wheel. A large number of experiments were made in determining the most desirable metallurgical features. A tyre material was desired with an inherent tensile strength about equal to that of rolled steel tyres, but which under special treatment would develop a much higher elastic limit and tensile strength to the desired depth, thereby presenting to the rail a wearing tread possessing a high degree of toughness combined with hardness, along with sufficient ductility to resist the service stresses resulting from rolling action, hammer blows, brake-block heating, slippage, etc.

The most successful combination was arrived at by utilising a high-grade commercial cast steel of

relatively low-carbon content; that portion of the metal which goes to make up the tyre portion having added to it sufficient manganese to provide the strength and wear-resisting qualities so much desired. The manganese is added in the form of finely-divided 80 per cent. ferro-manganese.

Having developed this differential composition in a one-piece structure, the next problem was the matter of suitable heat treatment. As a first operation a standard annealing treatment was evolved. After this annealing the wheels are put through the finishing operations, including the turning of the tread to contour. The tyre portion of manganese steel is then given a special water-toughening quench, in such a manner as to produce a tread metal with the particular combination of toughness, hardness, and high tensile properties desired. This heat treatment is followed by various quality tests as part of the final inspection before the wheel is despatched for service.

In 1907 and 1908 the Davis wheel began to be purchased in larger quantities for passenger, goods, locomotive tender, and engine truck services. Since that time its use has steadily extended, until to-day there are approximately a million of these wheels running. It is interesting to note that there has never been a single accident chargeable to the failure of a Davis wheel. Those familiar with railway conditions in America will readily appreciate that no more abusive conditions exist under which a railway wheel could be developed and perfected. Wheel loads are very heavy; permanent way for the most part is inferior to that in this country. Trains are heavy, and

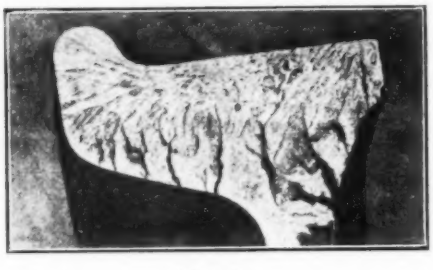


FIG. 2.

in many parts of the country severe gradients exist. Further, continuous braking is universally employed. All goods trains are fitted with air-brake equipment.

In strictly goods service so few of the early wheels applied have been removed from under the cars that no adequate idea can yet be formed as to what the actual average life of these wheels will be in this class of service. For instance, in the case of one American railway some 67,000 33-in. Davis wheels were placed under 40- and 50-ton goods stock during 1911, 1912, and 1913. To date less than 5 per cent. of these wheels have been removed from service for all causes, and this despite the relatively high annual mileage figures for rolling stock in America. The fitting of these wheels under new rolling stock in America is extending at such a rate that the production for the first half of the present year was approximately at the rate of 300 wheels daily. This new stock is mostly of 40, 50, 55, and 70 ton capacity, the cars being of bogie construction and fitted with eight wheels.

The tendency of the American railways serving the great anthracite and bituminous coalfields is for coal cars of heavier and heavier capacity, with its correspondingly greater demands in the way of wheel service, and in this the Davis wheel is playing an increasingly important part. Coal cars of 70-ton capacity are no longer unusual, and Davis wheels have been fitted to an appreciable number of cars of 100-ton and 120-ton capacity. A considerable percentage of the American production of these wheels goes into locomotive tender service, both passenger and goods, where admittedly the conditions for wheel service and wear are the most severe.

As previously mentioned, a new plant for the making of these wheels is now in operation at the Scunthorpe Works of John Brown & Company, Limited, and a description of the method of their manufacture and the special plant required is given below.

In addition to purely manufacturing problems certain slight changes in design were found advisable. For instance, in this country the universal requirement of sprag holes in all wheels for goods stock is something unusual to the American practice. The standard type of Davis wheel developed for wagon use in this country has three 6-in. diameter sprag holes in the plate in accordance with the present standard requirements. In the matter of design the Davis wheel possesses certain advantageous features. Fig. 1 shows the special corrugated design of the plate portion, and the manner in which these corrugations or waves in the plate are deepest at their junction to the hub of the wheel. This design permits of maximum strength and load-carrying capacity combined with minimum weight. It provides amply for the required lateral strength and ability to resist distortion due to side-thrust. It gives stiffness without extreme rigidity, and a distribution of metal which to the greatest possible extent obviates the development of shrinkage strains. The corrugations are a fundamental part of the design of all Davis wheels in the larger diameters. For small-diameter wheels, such as

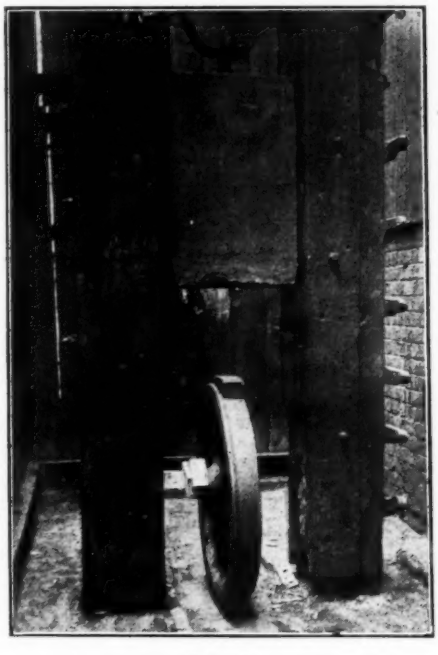


FIG. 3.

tramway wheels and narrow-gauge railway wheels, the common disc type of plate is used.

It is to be noted that with the one-wear principle of the Davis wheel an excessively thick tyre is unnecessary, inasmuch as no provision must be made as in the case of tyres for metal for re-turning operations. Important savings in weight can be effected. For instance, in the case of a standard 20-ton wagon in this country there is a direct saving of about 8 cwts. per wagon with Davis wheels, as compared with the present tyred type of wheels. It only need be mentioned that the reduction of dead and non-paying load wherever possible is one of the principles of economical transportation.

Steel used for the Davis wheel is made by the Robert acid Bessemer process. The steel in the ladle is of ordinary mild steel composition—similar, in fact, to that in common use for the making of cast-steel locomotive wheel centres. A typical analysis is as follows:—C, 0.22; Mn, 0.70; Si, 0.30; P, 0.045; S, 0.045 per cent. Before the commencement of the pouring operation the mould is revolving, speeds up to 100 r.p.m. being employed. The ferro-manganese injection—introduced to produce an alloy of the desired composition—is limited to the first metal entering the mould, and only to that which goes to make up the tyre section. The centri-

fugal action along with the symmetrical design of the mould ensures proper deposition of the manganese alloy. Completion of the ferro-manganese injection in no way interferes with the continuity of flow of the molten steel, which continues to fill up the mould forming the plate and boss in mild steel. The resulting product is therefore an integral casting in the fullest sense. Centrifugal casting in this case serves a twofold purpose: first, for accomplishing the differential composition, and, secondly, for developing a fluid compression in the steel, gaining thereby a high degree of solidity. After shaking out of the moulds the wheels are given an annealing treatment, and after removal of heads, general fettling operations, etc., they are rough bored, and then passed to the lathe.

The machined wheels are now submitted to the water-toughening treatment. This operation needs particular explanation, inasmuch as hardness, toughness, and high-tensile qualities are developed on the tread and the inside face of the flange—*i.e.*, where resistance to abrasion is really needed. Quenching water is applied by means of special rings in a large number of small jets. No water comes in contact with the back side of the flange. The whole wheel is first heated to the desired temperature. During the water application there is but little loss of temperature in the plate and boss, which are allowed to cool down slowly, thus further inducing a soft condition in these portions of the wheel. It is interesting to note that there is no measurable difference in wheel diameter before and after the hardening treatment. Uniformity of treatment is assured by a definite control of the governing factors, such as temperature of the wheel before applying the water, quenching time, volume and temperature of quenching water.

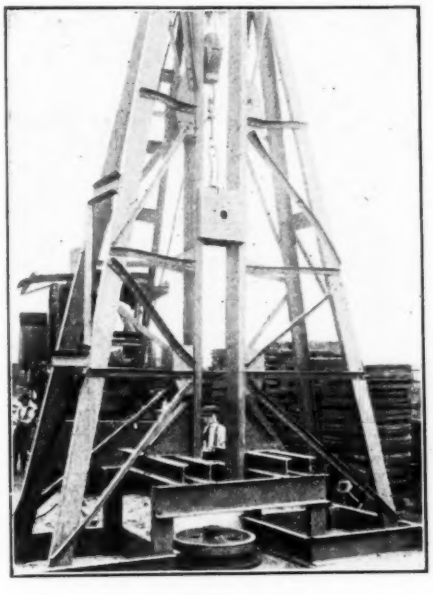


FIG. 4.

Fig. 2 shows a typical tyre structure. Something akin to armour-plate is developed—that is, there is a hard exterior to the desired depth, but backed by a supporting material in a softer and tougher condition. The wave-like fibrous structure, indicative of toughness, will be noted. Flange shock tests have shown the great abundance of strength of the flange of the Davis wheel due to this differential hardness. The grain-size of the structure is extraordinarily fine as a result of the two heat treatments, and will give some understanding how it is possible to produce a wheel tread that in service literally keeps its own contour. The wearing qualities are probably due to a combination of composition, treatment, and metal density as a result of fluid compression and not to hardness in itself. Scleroscopic hardness figures range around 60 to 65. Tests have been made in the determination of the relative coefficients of adhesion of the Davis wheel, the steel-tyred wheel, and the chilled-iron wheel. These tests were made at various speeds up to 60 miles per hour, and were carried out independently by the railway engineering department of one of the large American Universities. The results of the tests showed favourably for the Davis wheel.

The tread will yield or flow a trifle under excessive loads, but not to the extent of tyres, which are well known often to roll or flow over the edge of the rim. In America many Davis wheels are regularly operating under the heaviest locomotive tenders, which when fully loaded with coal and water weigh about 200,000 lbs. Tbis load is carried on eight wheels, giving an individual wheel load of 25,000 lbs. When sprag holes are required, as is the case in many wheels for goods service, these are machined in the plate subsequent to the hardening treatment.

As part of the final inspection each wheel is subjected to a ring test, consisting in a falling block of steel weighing 3 cwts. from a height of 5 ft., the wheel being supported on a rigid steel base weighing 5 tons. Further, each wheel must pass an individual hardness test before being passed for service. Finally, the wheels are exactly mated for diameter, and despatched in pairs for mounting on the same axle. A circumferential steel tape is used for this purpose, which permits extreme accuracy in the mating.

Destruction Test.

The following is a description of a test to destruction of a standard Davis wheel for British wagons. The wheel was first placed in a running position, resting on a 5-ton steel base on a concrete foundation. Fig. 3 shows the wheel in position for test. A 1-ton tup was allowed to fall on the tread of the wheel from a height of 5 ft. The wheel was then turned around 90 deg. and the test repeated. The wheel was unaffected by these tests. The same wheel was then placed in a horizontal position on a circular steel ring, resting on a 5-ton steel block, the whole being on a concrete foundation. Fig. 4 shows the wheel in position for this horizontal test. A 1-ton tup was then allowed to fall on the boss from a height of 10 ft. The wheel remained sound and without fracture, the boss being deflected and taking a permanent set of about $\frac{1}{4}$ in. The wheel was again placed in position for the horizontal test and the 1-ton tup allowed to fall on the boss from a height of 20 ft. One small fracture was started in the plate from one sprag hole. The wheel was again placed in a horizontal position, and the 1-ton tup allowed to drop again on the boss from a height of 20 ft. The fracture was extended further into the plate. The tenacious condition of the metal was shown by this test, as well as the inherent safety of the wheel as a structure.

Equilibrium at High Temperatures in the Iron-Carbon-Silicon System.

By M. L. BECKER, B.Met. (University of Manchester).

(*Abridged.*)

The condition of the carbon is the principal factor determining the mechanical and some physical properties of cast iron, and therefore the possibility of control of this condition is of considerable interest in the foundry. The concentration of carbon in solution in iron, in equilibrium with free carbon, varies appreciably with temperature, so that exact knowledge of this equilibrium is essential when considering the effect of rate of cooling, or subsequent heat treatment. Many investigators have studied the question of stable equilibrium in commercial alloys and in the pure iron-carbon alloys, but very little work has been published concerning the influence of varying amounts of a third element upon the latter.

Charpy and Cornu-Thenard[1] have studied the influence of silicon on the solubility of carbon in

[1] Charpy and Cornu-Thenard, "Journal of the Iron and Steel Institute," 1915, No. I, p. 276.

iron. These investigators used a series of cast alloys containing roughly 2 per cent. of carbon, and varying in silicon from 2.23 per cent. to 6.77 per cent. First of all, the carbon was precipitated as graphite by annealing the alloys at 1,000 deg. C. for three hours and cooling slowly (80 deg. C. per hour). This was followed by heating the alloys at a constant temperature varying from 600 to 1,000 deg. C. for one to three hours, and finally quenching. The specimens were analysed for total carbon and graphite, the difference being taken as the carbon in solution at the temperature of the experiment. Charpy and Cornu-Thenard's general conclusions are given in Table I, although a reference to the original Paper will show that the actual experimental values are to some extent inconclusive. Probably this was due to the method

TABLE I.—*Results Obtained by Charpy and Cornu-Thenard.*

Silicon per cent.	Carbon per cent. in Solution.				
	600° C.	700° C.	800° C.	900° C.	1,000° C.
2.23	—	—	0.6	0.8	1.1
3.16	—	—	—	0.7	0.9
4.22	—	—	—	0.2	0.7
5.84	—	—	—	—	0.3
6.77	—	—	—	—	0.2

of analysis, which although generally considered the most reliable, is open to some objections when used for small specimens where the percentage of graphite frequently varies in different parts. The experiments to be described have been conducted under different conditions in order to gain further knowledge regarding equilibrium in this system.

Charpy[2], Iokibe[3], and Northcott[4] have shown that temper carbon is indistinguishable chemically and physically from graphite, and it is therefore justifiable to assume that the two are identical. Upon this basis it seemed advisable to investigate the equilibria by cementing in graphite a series of pure iron-silicon alloys until saturation is reached. That the carburisation of iron by solid

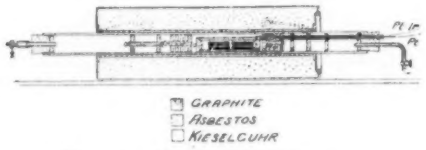


FIG. 1.—CARBURISING FURNACE.

carbon depends, from the practical standpoint, upon the presence of a gas phase has been proved by several investigators, notably Guillet and Griffith[5], Giolitti and Astorri[6], Weyl[7], and Charpy and Bonnerot[8]. When, as in the experiments to be described, the carburising chamber is first filled with air, this gaseous vehicle will consist of nitrogen and the two oxides of carbon in equilibrium with carbon. If the theory of Honda and Murakami[9] be accepted, namely, that graphitisation in iron-carbon alloys is largely due to the presence of the two oxides of carbon in the solid metal, it becomes increasingly evident that the equilibrium at any temperature with respect to carbon in solution should be the same whether graphitising a high-carbon alloy or carburising a low one. In the case of the pure iron-carbon alloys experimental evidence to this effect is not lacking. Charpy[10], by cementing iron in wood charcoal at 1,000 deg. C., obtained about 1 per cent. of carbon in solution, which figure agrees closely with the value he obtained by annealing pure white or grey iron at the same temperature. Gutowsky[11] carried out carburising experiments on shavings of iron, but obtained high results, probably corresponding more nearly with cementite than with graphite equilibrium, on account of the powerful carburiser employed (mixture of amorphous carbon and barium carbonate).

[2] Charpy, "Revue de Métallurgie," Vol. V, p. 75.
[3] Iokibe, "Science Reports, Tôhoku University," No. IX.
[4] Northcott, "Journal of the Iron and Steel Institute," 1923, No. I, p. 491.
[5] Guillet and Griffith, "Revue de Métallurgie," Vol. VI, p. 1013.
[6] Giolitti and Astorri, "Gazzetta Chimica Italiana," 1910, Vol. XL, p. 1.
[7] Weyl, "Métallurgie," 1910, Vol. VII, p. 440.
[8] Charpy and Bonnerot, "Comptes Rendus," 1910, Vol. CL, p. 173.
[9] Honda and Murakami, "Science Reports, Tôhoku University," September, 1921.
[10] Charpy, "Comptes Rendus," 1907, Vol. CXLV, p. 1277.
[11] Gutowsky, "Métallurgie," 1909, Vol. VI, p. 731.

Cementation Experiments.

Armco iron and three pure iron-silicon alloys containing approximately 1½, 2½, and 4 per cent. of silicon were used as basis materials in the present investigation. The analyses of these materials are given in Table II:—

TABLE II.—*Analyses of Raw Materials Used.*

Material.	No.	C.	Si.	Mn.	S.	P.
Armco.. ..	—	0.03	0.01	—	—	—
Silicon alloy ..	1½	0.10	1.33	0.22	0.024	0.032
,, ,, ..	2½	0.07	2.54	0.065	0.030	0.027
,, ,, ..	4	0.06	4.22	0.09	0.026	0.025

The silicon alloys were received in the form of strips ⅜ in. thick and 8 in. wide. The strips were cut longitudinally into bars ⅜ in. square and 8 in. long, which were then turned down into rods $\frac{5}{16}$ in. dia. Short lengths about 1¾ in. long were used in each experiment. The Armco which was received as $\frac{7}{16}$-in. rod was turned down to $\frac{5}{16}$-in. for the sake of uniformity, but it was subsequently found that the high rate of carbon penetration in the case of iron containing no silicon more than counterbalanced the effect of the increased depth to be cemented during each experiment. The cementing medium was prepared from graphite electrodes, only that portion passing through a 90-mesh sieve being used. The powder was not subjected to any purifying treatment, as it was found that a sample which had been used for carburising specimens at 1,000 deg. C. contained 99 per cent. of carbon, and that the remaining 1 per cent. in that instance was due to the presence of iron scale. It cannot, however, be assumed that the graphite was entirely free from impurities such as occluded gases, evidence of

TABLE III.—*Mean Carbon Content calculated from Increase in Weight during Carburisation.*

Experiment No.	Temperature. Degs. C.	Material.	Initial weight of specimen. Grammes.	Carbon per cent.			
				Actual (by analysis).	Apparent (from increase in weight).		
				0 hrs.	74 hrs.	145 hrs.	313 hrs.
C6	940	(1)	32.4655	0.03	0.68	0.82	0.90
		Armco (2)	18.7650	—	—	0.90	0.91
		(3)	11.5890	—	0.88	0.95	0.98
		1.33% Si	18.1665	0.10	—	0.81	0.81
		2.54% Si	17.6880	0.07	—	0.42	0.50
		4.22% Si	16.0150	0.06	—	0.17	0.17
				0 hrs.	41 hrs.	158 hrs.	324 hrs.
C17	1100	Armco	19.2455	0.03	1.32	1.47	1.53
		1.33% Si	18.9470	0.10	1.07	1.24	1.38
		2.54% Si	20.3575	0.07	0.52	0.60	0.65
		4.22% Si	19.4820	0.06	0.08	0.10	0.10

which has been frequently noted in connection with other work.

A section of the furnace used (Fig. 1) is included in order to show the comparatively long winding and uniform temperature obtained over the entire length of the graphite carburising box. The latter with lid and also the ends of the heat-insulation plugs were turned from the same electrodes as were used in the preparation of the carburiser. The pressure in the furnace was the same as that of the atmosphere. Under these conditions there was practically no difference in temperature from one end of the carburising box to the other, and it was assumed that, given sufficient time, the gas surrounding the specimens would reach equilibrium with graphite at the temperature of the experiment, and that any convection currents at the ends of the furnace would not interfere with the establishment of that equilibrium. In order to find out the variations in temperature due to slight fluctuations in the voltage, a 300-hour continuous record was taken during the carburising at 1,100 deg. C. It was found that the rise and fall of temperature only amounted to + 5 deg. C., except at a certain hour each day, when for a

period of two hours out of the twenty-four the temperature reached 10 deg. C. above the normal.

It was realised during the early stages of the work that the time required for saturation would be considerable, and that furthermore some method would have to be adopted in order to find out when equilibrium had been reached. Campbell, Fink, and Ross[12], when obtaining equilibrium in dry hydrogen between pure iron and steels varying in carbon content, found that the increase or decrease in carbon content could be determined by weighing the individual specimens before and after the equilibrium treatment. A similar method was adopted in the present experiments, it being found convenient to weigh the specimens after approximately 40, 160, and 300 hours, the intention being to allow an ample margin of time undisturbed during the final stage.

At the beginning of each experiment and after each weighing the specimens were packed in graphite in the carburising box, and the whole introduced into the furnace held at the required temperature. The time at which the temperature of the box reached 900 deg. C. was taken as representing the commencement or continuation of carburisation, although from one to three hours usually elapsed before the temperature of the experiment was reached. At the end of each stage the box containing the specimen was withdrawn and allowed to cool in air. When cold, the specimens were rubbed free from adhering graphite, washed in water, dried, and weighed.

Table III gives the weight of specimen carburised, and the apparent carbon content at each stage for two temperatures—940 deg. C. and 1,100 deg. C. The values for apparent carbon content have been calculated by adding the percentage of carbon shown by the increase in weight to the initial percentage. These values are shown graphically in Figs. 2 and 3. The dotted line in Fig. 3 is the true carburisation curve for a 30-gramme specimen of Armco included in experiment C17. The actual percentage of carbon is given in Table III, experiments C17 (*a*) and (*b*), after which it reaches the same value as the 19-gramme specimen in C17 (*c*). It will be seen that the percentage of carbon calculated from the gain in weight is not in accordance with the actual percentage determined by analysis, and the appearance of the specimens suggested that these discrepancies were due to an indefinite amount of surface oxidation and consequent scaling. For this reason the curves for the intermediate temperatures are not reproduced, although each indicated that sufficient time had been allowed to ensure the limit of carburisation being reached.

[12] Campbell, Fink, and Ross, "Journal of the Iron and Steel Institute," 1923, No. II, p. 173.

Consideration of Results.

The results of sixteen experiments are given in Table IV. Fig. 4 shows graphically the percentage of silicon in the original alloys plotted against the carbon introduced at different temperatures, namely, 900, 910, 915, 940, 990, 1,045 and 1,100 deg. C., experiment numbers C10 (*b*), C9 (*b*), C12, C6, C15, C16 (*b*), and C17 (*c*) respectively. Cylinders of standard size were used in each experiment at temperatures of 920 deg. C. and above, in addition to which at least one specimen of Armco of a larger diameter ($\frac{7}{16}$ in.) was carburised in the experiments at 940 deg. C. and above, bringing the total weight charged to approximately 100 grammes. It should be noted that experiment C5 was abnormal in that about 50 grammes of white iron were introduced into the furnace along with the usual charge to be carburised. The partially annealed white irons were removed at the conclusion of the first period of 72 hours, but it is to their presence during the early stages of carburisation that the high carbon content of the 4.22 per cent. silicon alloy must be ascribed.

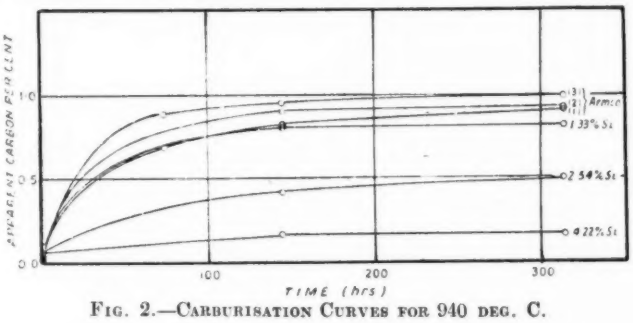


FIG. 2.—CARBURISATION CURVES FOR 940 DEG. C.

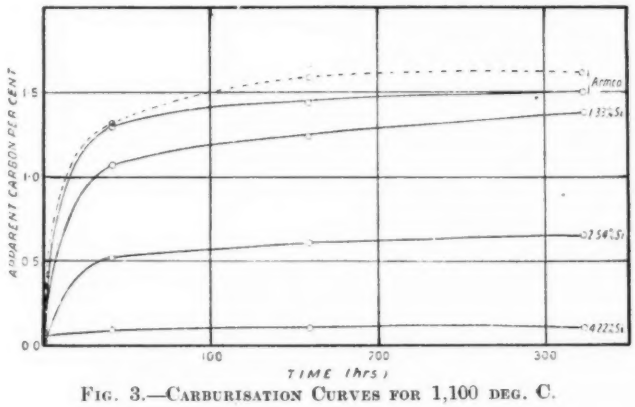


FIG. 3.—CARBURISATION CURVES FOR 1,100 DEG. C.

The microstructures showed that silicon had very little influence on the type of structure apart from increasing the grain-size. No attempt was made to measure the grain growth during carburising. Some difficulty was experienced in the etching of all the carburised alloys in spite of every precaution to avoid staining. The best results were obtained by washing the polished specimen in alcohol both before and after etching in the usual saturated solution of picric acid in alcohol. The pearlite was not particularly well laminated in any of the specimens, but this was quite to be expected in view of the comparatively rapid rate at which they were cooled through the A1 point (approx. 50 deg. C. per minute). The carbon content of C5 (4.22 per cent. Si and 0.17 per cent. C.) was in excess of the equilibrium content (0.09 per cent.).

The reason for this difference has been already given. The relative amounts of ferrite and pearlite shown, corresponding with only 0.17 per cent. carbon, were striking evidence of the effect of silicon in lowering the carbon content of the pearlite eutectoid.

With regard to carburising in graphite at temperatures between 800 and 900 deg. C., preliminary investigation seemed to show that this was either impossible or else that the time required was excessive. For this reason small specimens ¼ in. dia. and 1 in. long were prepared and packed in graphite in a short graphite box. The rest of the uniform temperature portion of the furnace was occupied by ½-in. dia. fireclay tubes containing a mixture of graphite and turnings of the materials to be carburised.

TABLE IV.—*Carbon Content of Carburised Alloys.*

Experiment No.	Temperature. Degs. C.	Duration of cementation (hrs.) Successive periods.	Total	Combined Carbon per cent. Armco	1.33% Si.	2.54% Si.	4.22% Si.
C7	800	24, 167	191	0	0	0	0
C8	850	67, 65, 45	177	0	0	0	0
C10 (*a*)	900	24	24	0.17	—	—	—
C10 (*b*)	900	24, 26	50	0.19	—	—	—
C9 (*a*)	910	89	89	0.26	0	0	0
C9 (*b*)	910	89, 116	205	0.26	—	—	—
C14	910	310	310	0.23	—	—	—
C12	915	117	117	0.32	—	—	—
C6	940	74, 71, 168	313	0.81	0.64	0.41	0.06
C15	990	41, 119, 135	295	0.91	0.73	0.55	0.11
C16 (*a*)	1045	41, 117	158	1.26	—	—	—
C16 (*b*)	1045	41, 117, 157	315	1.21	0.96	0.66	0.08
C5	1100	72, 96	168	1.61	1.30	0.60	0.17
C17 (*a*)	1100	41	41	1.30	—	—	—
C17 (*b*)	1100	41, 117	158	1.58	—	—	—
C17 (*c*)	1100	41, 117, 166	324	1.62	1.34	0.75	0.09

In experiments C7 and C8, conducted at 800 and 850 deg. C. respectively, no carburisation was obtained either of the turnings or of the ½-in. specimens. On the other hand, an appreciable amount of oxide of iron was formed on the surface of the specimens of Armco whilst the turnings were oxidised throughout. This effect was so marked after the first period in experiment C8 that a slow stream of nitrogen was passed through the furnace at the beginning of the second and third periods in order to lower the partial pressures of carbon monoxide and carbon dioxide taking part in the equilibrium:

$$C + CO_2 \rightleftarrows 2CO.$$

It was thought that the lowering of the pressure and the consequent shift of equilibrium towards the right might keep the conditions away from those of oxidation without seriously affecting the degree of cementation. The result of experiment C8, however, shows that even after this precaution no carburisation took place. Finally, in a further experiment a specimen of Armco containing 0.26 per cent. of carbon was completely decarburised and oxidised to an average depth of $\frac{1}{16}$ in. by treatment in graphite for 144 hours at 850 deg. C.

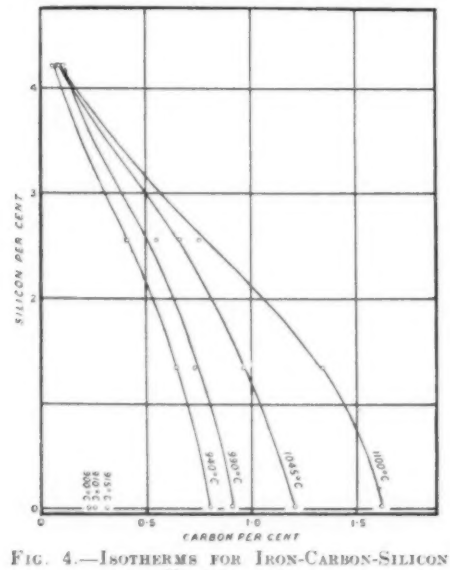


FIG. 4.—ISOTHERMS FOR IRON-CARBON-SILICON EQUILIBRIUM.

Turnings only were used in experiments C10 (*a*) and (*b*) at 900 deg. C., the carbon content being estimated by colour. In experiment C9 (*a*) no carburisation was found on examining the silicon alloys, although the specimen of Armco was carburised appreciably. After magnetically separating the small quantity of graphite powder mixed with the Armco turnings their combined carbon content was determined by wet combustion, giving the value 0.26 per cent. carbon for equilibrium at 910 deg. C. Samples of American washed iron and silicon-bearing white cast iron were introduced along with the Armco in experiment C14 at 910 deg. C. Even after 310 hours the silicon irons were not completely decarburised in the centre, although the outer zone consisted of ferrite. The carbon contents as demonstrated micrographically were practically identical, which demonstrates that a state of equilibrium had been very nearly reached from opposite directions.

From the isothermal diagram (Fig. 4) it is possible by interpolation to obtain for each temperature a series of values for carbon in solution corresponding with anything from 0 to 4 per cent. of silicon. Table V gives the values found in this way, and Fig. 5 their graphical representation.

TABLE V.

Silicon per cent.	Temperature (Degrees C.). 800.	850.	910.	940.	990.	1045.	1100.
0	0.00	0.00	0.26	0.81	0.91	1.21	1.62
1	,,	,,	0.00	0.70	0.80	1.03	1.43
2	,,	,,	,,	0.53	0.63	0.80	1.03
3	,,	,,	,,	0.30	0.38	0.48	0.55
4	,,	,,	,,	0.10	0.14	0.14	0.16

On comparing these values with those of Charpy and Cornu-Thenard given in Table I it will be seen that the agreement is not good. Apart from the carbon content the analyses of the two series of alloys are very similar and justify a comparison being drawn. According to Charpy and Cornu-Thenard, the values for carbon in solution are in excess of those given in Table V, particularly at temperatures below 950 deg. C. A possible explanation of this seems to be that in the experiments of Charpy and Cornu-Thenard the carbon in solution may not have been completely graphitised before re-solution at a constant temperature. If this be true, an indefinite amount of combined carbon would remain in the alloys, and if much in excess of saturation at the lower temperatures it is highly probable that the subsequent annealing at, say, 800 deg. C. for one and a-half hours would not suffice to graphitise the excess. This would be particularly true of the alloys containing less than 4.5 per cent. of silicon now under comparison.

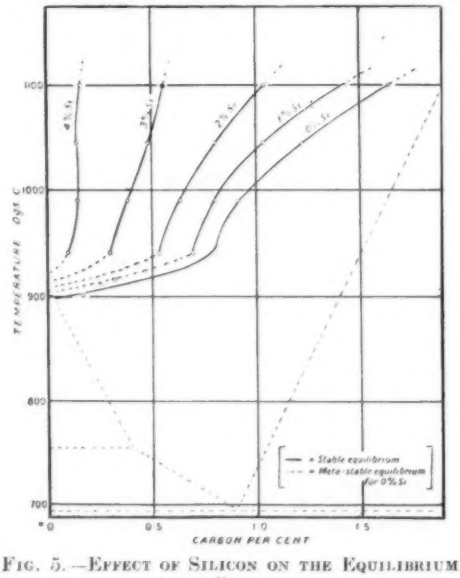


FIG. 5.—EFFECT OF SILICON ON THE EQUILIBRIUM WITH GRAPHITE.

That the accuracy of these results may be questioned is also borne out by the fact that one of

the authors, Charpy, in conjunction with Grenet[13], had previously published a few results showing the influence of silicon on the equilibrium with carbon. Thus at 1,100 deg. C. the silicon contents of 0.07, 0.27, 0.80, 1.25, and 2.10 per cent. were associated with combined carbon contents of 1.74, 1.93, 1.26, 1.02, and 1.00 respectively, showing on the whole a good agreement with the values now obtained by carburisation. Later, in a Paper to which reference has already been made, Charpy draws the conclusion that in a pure iron-carbon alloy stable equilibrium at 1,000 deg. C. is reached when there is 1 per cent. of carbon in solution, which value has also now been confirmed by carburisation. In fact, the carburisation curve for pure iron between 1,100 and 940 deg. C. is in good agreement with results which have been obtained by other investigators. Below these temperatures the curve has usually been produced to meet the A3-2 line of the metastable diagram, but carburisation data indicate that the curve bends to the left to meet the A3 line about 900 deg. C.

Theoretically, as Hayes, Diederichs, and Flanders[14] have pointed out, when the curve meets the A3 or the A3-2 line, another phase (ferrite) makes its appearance in the system, thus reducing the decrees of freedom to nought. This results in the simultaneous precipitation of ferrite and graphite, forming what has been called the graphite-ferrite eutectoid. If the results obtained by carburisation at 910 deg. C. are the same as those which would be obtained by very prolonged annealing of, say, white iron at the same temperature, then it would appear that the temperature of formation of the graphite-ferrite eutectoid in the absence of silicon is about 900 deg. C., and that it contains only approximately 0.05 per cent. of carbon. The effect of silicon would be to raise the temperature of formation slightly without appreciably affecting the composition.

The above research has been carried out during the past year in the Department of Metallurgy of the University of Manchester. It has been extended and completed as one section of a wider field now under investigation for the British Cast Iron Research Association. Thanks are due to the Council of the above Association for permission to publish the later results. The author also takes this opportunity of thanking Professor F. C. Thompson for his kindly supervision and interest during the whole course of the work.

Heat-Resisting Cast Iron.

Monsieur Levi Answers Criticisms.

In a communication addressed to the President of the Institute of British Foundrymen (Mr. John Cameron), Monsieur André Levi, the author of the paper on "Heat-Resisting Cast Iron," read before the Glasgow Conference, writes:—

I have received a copy of THE FOUNDRY TRADE JOURNAL containing the discussion which took place upon my Paper. As I was unable to be present at the Congress, I would appreciate the publication of the following reply to the criticisms which were made:—

Most of the criticisms were directed against a few lines which were devoted to Diesel engine castings where, as specified in my Paper, the castings are subjected to high temperature conditions, *such as the piston*. It appears to me that, so far as this subject is concerned, there has been a slight misunderstanding. It is established that cast iron having high silicon content has been rejected by practical men, but it is questionable whether this does not arise from the fact—special preparation excepted—that almost invariably that when the silicon content is greater than 2.0 per cent. the total carbon content is high.

I should have liked to know if the members who have, quite rightly, rejected silicon contents of 2.0 per cent. are prepared to discuss such cast iron but, *associated with low total carbon content*. I still believe that, in the absence of chromium (Text C.R.), the principal element to ensure a high resistance to heat is a low graphite content distributed in thin plates or round nodules.

If my memory does not fail me, Mr. F. J. Cook, for the *only Diesel engine casting* I referred to in my Paper, that is, the piston, has formally recommended in a very remarkable memoir a $\frac{\text{silicon}}{\text{total carbon}}$ ratio, which should give a figure ranging between 0.7 and 0.8 ("Engineering," 1920). This, with a total carbon of 3.0 per cent., gives a silicon content of between 2.0 and 2.25 per cent. Unfortunately, the original text is not available to me at the moment, and I am quoting from an abstract which appeared in "Revue de Métallurgie." As for other castings, it is established that one should reduce the silicon content according to the mass of the casting, and in certain cases do this until a figure of 1.0 per cent. is reached, as Mr. Cook has outlined. I am still of opinion that for pistons and cylinder jackets this figure is too low. Mr. J. S. G. Primrose is certainly in error in seeing on page 8 of my Paper confirmation that cast iron is not permeable to gas at high temperatures. I said exactly the opposite. The words used were "To accept Outerbridge's explanation, it is also at the same time necessary to accept that cast iron is not permeable to gas at high temperature." (Pour admettre l'explication d'Outerbridge, il faut admettre en même temps qua la fonte n'est pas perméable au gas à haute température). But *I did not accept Outerbridge's explanation*, and I showed later how the experiments of Kikuta contradicted this hypothesis. So far as the relationship between low total carbon and compact graphite is concerned, which was referred to by Mr. Primrose, I would draw attention to the fact that if compact graphite is obtained by other means it is nearly always associated with low total carbon. Howe, in his classical work on the Metallography of Iron and Steel, when dealing with certain irons containing compact graphite, states in the French edition:—"Malheureusement, il y'a lieu de croire que dans tous ces cas, cette compacité du graphite coencidait avec une teneur en graphite exceptionnellement basse, suffisante pour en expliquer la compacité"—total carbon, 3.16 per cent. (Unfortunately, there is every reason to believe that in all these cases the compactness of the graphite coincides with an exceptionally low graphite content, sufficiently so to explain this compactness.)

I can only state my complete agreement with the observations of Mr. Donaldson on the usefulness of chromium and tungsten (?) (French T).

Generally speaking, it is a pleasure to me to recognise the great skill and authority of the British foundryman on everything appertaining to Diesel engines, and for this reason I only devoted a few lines to the subject. Also I attach considerable importance to the criticisms made. On the other hand, it is with the greatest astonishment that I have read the observations made by Mr. H. J. Young. This gentleman insisted upon a temperature of 650 deg. C. for Diesel engine pistons, whilst Hurst ("Iron Age," 1921) stated this temperature may reach 900 deg. C.

Further on, in speaking of cast iron for heating apparatus (pages 17 and 18 of my Paper), I state that several British and French experts recommend for this type of casting a silicon content of greater than 2.25 per cent. However, I specified quite clearly that I referred to castings having less than 3 to 4 m.m. section thickness, cast green, and afterwards machined. Personally, I find 2.25 per cent. silicon to be insufficient. Mr. Young, however, quotes my words, and apparently recommends even for these castings a low silicon. If this is his advice, then such ideas, when they refer to very thin sections, are not only contrary to theory, but also against the most elementary precepts of foundry practice. If he uses it, Mr. Young may be quite sure that he will obtain white, unmachinable and useless castings. It seems impossible to me that an opinion so contrary to established foundry practice has actually been put forward by Mr. Young, who, judging from the isolated severity of his criticism, ought to be a particularly eminent specialist. On the contrary, if it is an

[13] Charpy and Grenet, "Engineering," Vol. LXXIII, p. 625.
[14] Hayes, Diederichs, and Flanders, American Foundrymen's Association, October, 1924.

established fact that a silicon content of 2.25 per cent. silicon has been recommended by authorities whom Mr. Young would contest, and that he himself takes exception, without actually saying it, to my advice, that it is necessary to have as much as 3 per cent. Si, I would therefore refer him to other authors recommending 2.25 per cent. silicon, such as, for instance, J. J. Porter (Report of the Committee on Standards—American Foundrymen's Association, 1910); G. A. Dyer ("Iron Age," pages 175 to 225, 1922), and the well-known book by Grunwald, "Technique de l'Emaillerie Moderne," page 37 (Si = 2.20), etc.

Inter alia, Mr. Young questions the possibility of obtaining cast iron with a total carbon content of less than 3 per cent. and a silicon content of 2 per cent. This simply goes to show that he ignores the results obtained by simultaneously melting steel and ferro-silicon, which has been utilised in foundry practice for more than 15 years.

The Present Position of Grey Iron Castings.

The grey iron foundry industry, at least the Pittsburgh section of it, took hope from the talk and counsel of Dr. Richard Moldenke, who in a recent talk before the members of the Pittsburgh Foundrymen's Association not only reviewed what had happened since the termination of the war, but prescribed the remedies for the restoration of grey-iron castings to the place they occupied before giving ground under the competition of steel and malleable castings. Dr. Moldenke said that since the war the struggle had been a constant one for the foundryman in getting out of the materials that have been available the high quality of finished material that was persistently demanded. The general average quality of pig-iron had fallen, he said, because furnacemen were pressed to get out iron at a price so low that, taken with the high cost of ore, coke and labour, there was no escape from the use of scrap. This made for poorer quality pig-iron, since the lime took out only the sulphur and did not disturb oxidation.

Since washing of coal had largely ceased since the war, present-day beehive oven coke was running high in sulphur and in ash. He noted the increased use of by-product coke in the cupolas, but said that in using this grade it was well that it be laid out thin so that the iron will get the heat before the coke takes fire. The size of the coke was important in that if hot iron was desired, it was necessary that the coke be in large pieces, which were less likely to take fire than the small pieces, before imparting heat to the iron. The speaker mentioned the difficulties that the foundries now had in securing scrap in competition with the steel makers, who were taking grades that formerly found their sole use in the foundries.

Facing Low Price Demand.

Dr. Moldenke thought the investigation into sand was timely, as the Government took so much of the good sand during the war and the general run of foundries do not prepare their own sand. High labour costs are affecting everything used in the foundries, and with consumers generally seeking lower prices the grey-iron foundries are hit harder than the steel or malleable foundries, especially the steel foundries, because in making steel castings oxidation is continuous, and with oxygen out and ferromanganese in, good steel is made out of poor iron. The speaker also told the advantage possessed by steel foundries in the high percentages of steel scrap that could be used.

More Science Needed in Melting.

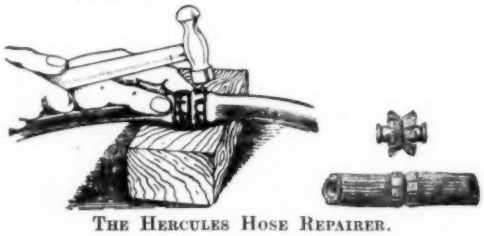
In pointing the way out for the grey iron founders, Dr. Moldenke asked for greater use of the laboratories and more science in melting. The electric furnace he regarded as too costly in these days for making castings, but did think there was a chance for economy in cupolas of smaller diameter than those now commonly employed in this country and in duplexing from cupola to electric furnace.

He believed the quality of pig-iron could be improved by greater use of alloys, and these he would add in the blast furnace in their original state instead of as ferro-alloys, mentioning the use across the water of briquettes of silicon running as high as 95 per cent. Greater care with melting cuts the variation in temperature of the iron and a cut in the charge would eliminate alternate hot and cold iron. A layer of coke of not more than 4 in. was advocated.

Gating was worthy of study to give the iron a chance in the casting. There was opportunity for saving in accurate cost keeping. Quick detection of the sources of defective work was possible by placing an inspector on the cupola platform and one in the sorting room. Moulding machines had become a necessity as a result of the shortage of men and what now was needed was a conveyor carrying the moulds. The speaker thought that while modern foundry construction was costly, it paid for itself in the attraction of workmen to light and well-ventilated plants. He believed education of the young men of the industry was a step in the right direction, not only because it resulted in getting these men away from the idea that they were mere machines, but the training fitted them for the more accurate work than now is demanded.—"Iron Age" Report.

A Useful Hose Repairer and Coupler.

In foundries where pneumatic pressure is utilised the management is often concerned at the high wastage of rubber hose, because so many of the bursts are due to carelessness, but however much care is exercised there will always be a certain amount of bursting, due to metal sparks. We recently investigated the Hercules repairer and coupling, which is marketed by the patentees, Messrs. Newton Sales Company, Limited, of Charterhouse Chambers, London, E.C.1. This "gadget," which is illustrated below, consists of a double brass nozzle, the ends of which are inserted into the two ends of the pipe cut through at the point at which it leaks. Claws made of



THE HERCULES HOSE REPAIRER.

mild steel are then hammered down on the hose, giving a solid, workmanlike joint capable of withstanding quite high pressures. The range of nozzles and couplings which are at present available includes $\frac{1}{16}$ in. for acetylene welding pipes, $\frac{1}{2}$ in. for pneumatic hose and "garden" hose for watering down sand, $\frac{5}{8}$ in, which will withstand 90 lbs. per sq. in.; the $\frac{3}{4}$, 1 and $1\frac{1}{4}$ in. sizes have not yet been tested to full capacity, but a minimum of 100 lbs. can be relied upon. Some of the nozzles are designed to detach by unscrewing in the middle, thus allowing pipes of great length to be made for temporary usage.

A Refractory Material Publication.

Jacketted in red covers, this new monthly journal devoted to the needs of the refractory industry consists of 38 pages, of which 16 are devoted to news. It is excellently produced on art paper, and costs 9d. per copy, post free, or 7s. 6d. per annum. There is in the first issue practically no technical matter, and until this condition is changed it can only be regarded as a newspaper for the trade. It is published from 9, Paradise Square, Sheffield, the proprietors being the Sheffield Refractories Company, Limited. We wish our new contemporary every success.

MESSRS. CAMMELL, LAIRD & COMPANY, LIMITED, are extending their Grimesthorpe (Sheffield) Steel Foundry.

THE coal and iron ore output of the Han Yeh Ping Company, Limited, from their mines near Hankow, for 1924, was 648,527,500 and 468,921,704 tons respectively.

Trade Talk.

THE NATIONAL GAS ENGINE COMPANY, LIMITED, have removed to Australia House, Strand, W.C.2.

THE IMPORTS of foreign iron ore at the Senhouse dock at Maryport last week amounted to 5,100 tons.

THE TYNE IRON SHIPBUILDING COMPANY'S yard, Willington Quay, is to be closed, owing to lack of work.

THE BRITISH THOMSON-HOUSTON COMPANY, LIMITED, have a six months' contract for the supply of Mazda lamps to the Southern Railway.

COX & DANKS, LIMITED, have just raised at Scapa Flow the "V78," a destroyer of 750 tons. The "V78" is the eighteenth boat to be brought up and the last of her class.

A FIRE OCCURRED at the premises of W. K. & C. Peace, Limited, steel and file manufacturers, of Mowbray Street, Sheffield, but was subdued before much damage was done.

YARROW & COMPANY, LIMITED, of Scotstoun, Glasgow, have recently secured an order for four Yarrow patent water-tube boilers with super-heaters and air-heaters for one of the London power stations.

MR. H. FIELD, for 10 years works manager and general manager to the Western Engineering Company, Swansea, has acquired the business of that company, and intends to carry on the business on his own account.

THE FAIRFIELD SHIPBUILDING AND ENGINEERING COMPANY, LIMITED, of Govan, have obtained an order for a second motor passenger and cargo vessel of 10,000 tons deadweight, 7,500 tons gross, and 8,000 h.p., from Bibby Bros. & Company, Liverpool.

Contracts Open.

Looe, Cornwall.—Pipes, etc., for the Looe U.D.C. Mr. G. H. Ivory, chartered civil engineer, Guildhall, Looe, Cornwall. (Fee £2 2s., returnable.)

London, S.E., September 18.—Tubes, etc., for the Director-General, India Store Department, Branch No. 14, Belvedere Road, Lambeth, London, S.E.1.

Chippenham, October 1.—Water mains, for the U.D.C. The Borough Engineer, Mr. A. E. Adams, High Street, Chippenham, Wilts. (Fee £2 2s., returnable.)

Prague.—Metals, for the Direction of Railroads, Prague South. The Department of Overseas Trade, 35, Old Queen Street, London, S.W. (Reference A.X. 2355.)

London, S.W., September 25.—Points, etc., for the South Indian Railway Company, Limited. 91, Petty France, Westminster, London, S.W.1. (Fee £1, returnable.)

Durban, S.A., October 2.—Valves, for the Borough of Durban. The Department of Overseas Trade, 35, Old Queen Street, London, S.W.1. (Reference No. A.X. 2363.)

Durban, S.A., October 2.—Pipes, etc., for the Borough of Durban. The Department of Overseas Trade, 35, Old Queen Street, London, S.W.1. (Reference No. A.X. 2362.)

Conway, September 18.—Providing and laying of about 1,160 yds. of 6-in. water mains, for the Corporation. Mr. F. A. Delamotte, borough engineer, Municipal Offices, Conway. (Fee £1 1s., returnable.)

Personal.

DR. R. J. ANDERSON, formerly metallurgical engineer to the U.S. Bureau of Mines, has identified himself with the Kant Skore Piston Company, of Cincinnati.

It was announced at the meeting of the Iron and Steel Institute at Birmingham, on Thursday, that Sir William Peter Rylands had accepted the presidency of the Institute for the year commencing May, 1926. Sir Wm. P. Rylands is chairman of the Moss Hall Coal Company, Limited, and the Partington Steel & Iron Company, Limited, deputy-chairman of the Pearson & Knowles Coal & Iron Company, Limited, and managing director of Rylands Bros., Limited. He is in addition president of the Iron & Steel Wire Manufacturers' Association, and is a past-president of the Federation of British Industries.

Obituary.

MR. J. M. PAUL, blast-furnace manager to the Stanton Ironworks Company, Limited, died last Sunday week.

Correspondence.

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

What is the Matter with British Industry.

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—From time to time we hear complaints on all sides of slack trade and no business. I am at a loss to understand the attitude of many English manufacturing concerns. As a small concern employing two hundred hands we are exceedingly busy and have been for the last four or five years, and we are continually extending our works and our output, also the number of employees engaged are continually increasing.

How different the country would be if all engineering firms could say the same, but we find in our business dealings that our friends in other engineering trades are either too lax to take up new manufactures or do not cater for the demands of the public. As an illustration, we were anxious to purchase two gross malleable iron castings, weighing 4 or 5 lbs. each, and several makers replied that they were too busy to quote us. Another of our requirements was two gross of spiral springs, and we had to wait nine weeks for delivery. We thought we should have had no difficulty in obtaining square bar iron 13/16-in. square, but we had to wait ten weeks for delivery.

We required a small repair job for our large ladle and the makers quoted us £12, which were rough gears only. We obtained a much superior article, that is to say, the gears were machine cut, for the small sum of £2.

If these cases frequently occur in a small works we have no doubt that in the larger concerns they are of much more frequent occurrence. Hence my title "What is the Matter with British Industry?"

Perhaps some of your readers may be able to make some comments on this matter.—Yours, etc.,

L. TIBBENHAM.

Gipping Works, Stowmarket.
September 14.

Company News.

Bengal Iron Company, Limited.—Interim dividend on preference shares passed.

Thames Welding Company, Limited, 146, Bishopsgate, London, E.C.2.—Capital £5,000 in £1 shares.

British Electric Transformer Company, Limited.—3½ per cent., less tax, on preference shares on account of arrears.

Markham & Company (1925), Limited, Broad Oaks Iron Works, Chesterfield.—Capital £5,000 in £1 shares. Forgers. Director: C. P. Markham.

James Brooks (Smethwick), Limited, 141, Lewisham Road, Smethwick.—Capital £8,000 in £1 shares. Iron merchants. Directors: H. Ford and J. Bissell.

J. P. Robertson, Limited.—Capital £3,000 in £1 shares. Iron dealers. Directors: J. P. Robertson, 10, Dean Terrace, Kilmarnock, and W. M. Moore.

Ferranti, Limited.—Total profit, £165,982; depreciation, £15,000; net profit, £67,644; reserve, £40,000; dividend, 20 per cent., tax free; carry forward, £33,313.

Stewarts and Lloyds, Limited.—Interim dividend on preference shares, 6 per cent. per annum; ditto, preferred ordinary, 10 per cent. per annum, payable on September 30.

J. Clayton & Company, Limited.—Capital £5,000 in £1 shares. Brassfounders, etc. Director: C. Marshall (per. gov. and chairman), Falcon Works, Sherwood Rise, Nottingham.

Nobel Industries, Limited.—Profit, £1,003,420; debenture interest, £72,733; cost of debenture issue, £2,977; balance at credit of profit and loss, £927,709; brought forward, £650,130; dividend, 9 per cent. on ordinary shares; balance available, £716,597; special investment reserve account, £50,000; carried forward, £666,597.

THE employees of the Suffolk Iron Foundry (1920), Limited, Stowmarket, had their annual outing last Saturday, when a visit was paid to the works of Messrs. Crompton & Company. During the tour of the works the various processes of motor manufacture provided a fascinating and interesting study to the foundrymen, who, by the way, manufacture the majority of the grey iron castings for this electrical concern.

IRON AND STEEL MARKETS.

Pig-iron.

MIDDLESBROUGH.—Conditions in the iron trade on Tees-side continue far from satisfactory, the demand both for home and export having reached almost a minimum level for this particular centre of the industry. In ordinary circumstances there is usually increased buying at about this period of the year, but on this occasion business is, if anything, hopelessly below the average, without at the moment any signs of an early improvement. At this week's market there was no sign of any inclination to depart from this attitude. The general quotation for No. 3 was only 68s. per ton, as against 69s. previously quoted, but the decline had no effect upon business. Prices, indeed, are but little guide in existing conditions, business being very largely a matter of individual negotiation, and dependent upon the position of a particular works at a given moment. No. 1 foundry was called 72s., No. 4 foundry 67s., and No. 4 forge 66s. 6d. per ton.

Business in the hematite section is unfortunately equally unpromising in outlook to that for general iron, with values weak and irregular. Quotations for East Coast mixed numbers now rule about 75s. per ton, with 6d. extra for No. 1 quality. On the North-West Coast Bessemer mixed numbers are nominally £4 5s., c.i.f. Welsh ports, £4 5s. 6d. per ton delivered at Glasgow, £4 8s. per ton delivered at Sheffield, and £4 15s. per ton delivered at Birmingham.

LANCASHIRE.—The demand for foundry pig in this district remains still on a much restricted scale, while reports of sales at lower prices are current in connection with Midland brands. Buyers of foundry iron in Manchester continue to do hand-to-mouth business mainly, and many of them are looking for lower prices. They seem to anticipate a level of 70s. for No. 3 in Manchester by the end of the year.

Metals.

Copper.—After various fluctuations of minor importance as regards intrinsic value, the market for standard metal appears to have steadied to round about £62 per ton, a rate at which a fair average business has been done during the week. For several months past the American copper refinery production has been running ahead of the smelter output. It is to be expected, therefore, that at least a slight decrease in the refinery production is impending. Current quotations :—*Cash* : Thursday, £61 17s. 6d. ; Friday, £62 2s. 6d. ; Monday, £62 7s. 6d. ; Tuesday, £62 12s. 6d. ; Wednesday, £62 10s.

Three Months : Thursday, £62 17s. 6d. ; Friday, £63 2s. 6d. ; Monday, £63 7s. 6d. ; Tuesday, £63 12s. 6d. ; Wednesday, £63 7s. 6d.

Tin.—Stimulated by a small improvement in consumptive demand on the tinplate makers' account, there is now a tendency of strengthening values of the metal, which is supported by the recent statistical returns, showing some decrease in the visible supplies. For the end of August an increase in the total visible supplies of anything up to 1,000 tons was very generally expected, but this anticipation was disappointed, and, in fact, a reduction of a few hundred tons was disclosed. Current quotations :—*Cash* : Thursday, £255 10s. ; Friday, £257 10s. ; Monday, £257 17s. 6d. ; Tuesday, £258 2s. 6d. ; Wednesday, £260 15s.

Three Months : Thursday, £258 2s. 6d. ; Friday, £260 2s. 6d. ; Monday, £260 5s. ; Tuesday, £260 12s. 6d. ; Wednesday, £263.

Spelter.—According to Rudolf Wolff & Company, rather more demand has been experienced on the part of consumers, and Continental producers still offer only sparingly, the position generally on the Continent showing recently some signs of improvement. The market, moreover, in the U.S.A. remains very firm, stocks are small, and prospects are good with regard to domestic consumption ; the price there continues to rule above London parity, and little disposition is shown to press sales for export. Current quotations : *Ordinary* : Thursday, £36 18s. 9d. ; Friday, £37 1s. 3d. ; Monday, £37 1s. 3d. ; Tuesday, £37 3s. 9d. ; Wednesday, £37 3s. 9d.

Lead.—In the market for soft foreign pig a more ample supply of metal, with only a quiet inquiry, has influenced values slightly, but on the whole the market may still be pronounced steady. A good deal of the earlier firmness was to some extent stimulated by the seamen's strike in Australia, and the possibility of supplies being thereby very seriously hampered, which occasioned a fair amount of bear covering. Current quotations :—*Soft foreign (prompt)* : Thursday, £38 15s. ; Friday, £39 ; Monday, £38 12s. 6d. ; Tuesday, £39 15s. ; Wednesday, £38 16s. 3d.

BLACKING,
PLUMBAGO,
CORE GUM,
WHITE DUST,
COAL DUST.

ESTABLISHED 1863

JAS. DURRANS & SONS, LTD.

PHOENIX WORKS, PENISTONE, near SHEFFIELD.

Telephone:
21 PENISTONE.

Telegrams:
"DURRANS, PENISTONE."

Manufacturers of

FOUNDRY EQUIPMENTS

LADLES,
FIRE BRICKS,
STONE FLUX,
CASTING CLEANERS,
PIPE NAILS,
SPRIGS,
WIRE BRUSHES,
BELLOWS,
CUPOLAS,
GANISTER,
LOAM AND SAND MILLS,
STUDS,
CHAPLETS,
BRUSHES,
CORE ROPES.
BUCKETS,
SPADES, Etc.

Write for Illustrated Catalogue on Blacking and Foundry Requisites, also for our latest Price List.

Bindo Broadcast No. 1

"BINDO" IS THE BEST BINDER

We offer
NO PRIZES
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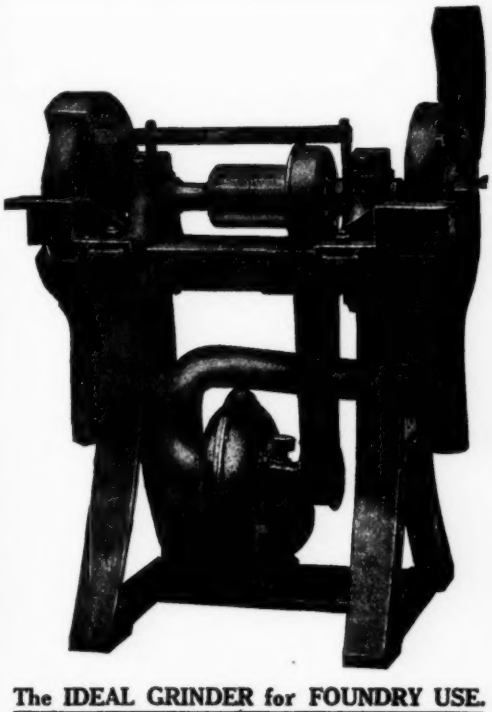

The IDEAL GRINDER for FOUNDRY USE.
(Supplied with or without dust collecting set.)
Stocked by Merchants in all the Large Towns.

Write for particulars to the Makers—
T. E. SALTER, LTD.
BLOOMFIELD TIPTON, STAFFS.

WEEKLY PRICE CURRENT.

COPPER.

	£	s.	d.
Standard cash ..	62	10	0
Three months ..	63	7	6
Electrolytic	68	10	0
Tough	65	5	0
Best selected ..	65	10	0
Sheets	93	0	0
India	81	0	0
Wire bars	69	0	0
Do. Sept.	68	10	0
Do. Oct.-Nov. ..	68	15	0
Ingot bars	68	10	0
H.C. wire rods ..	73	0	0
Off. av. cash, Aug.	62	13	6
Do., 3 mnths. Aug.	63	13	0
Do., Sttlmnt, Aug.	62	13	4½
Do., Electro, Aug.	68	7	9
Do., B.S., Aug. ..	66	3	1½
Aver. spot price copper, Aug. ..	62	13	4½
Do., wire bars, Aug.	68	12	1½
Solid drawn tubes		13¾d.	
Brazed tubes ..		13¼d.	
Wire		10d.	

BRASS.

Solid drawn tubes ..	12d.
Brazed tubes	13½d.
Rods, drawn	11½d.
Rods, extd. or rlld. ..	7½d.
Sheets to 10 w.g. ..	10⅜d.
Wire	10½d.
Rolled metal	9⅝d.
Yellow metal rods ..	7½d.
Do. 4 × 4 Squares	8d.
Do. 4 × 3 Sheets ..	8½d.

TIN.

	£	s.	d.
Standard cash ..	260	15	0
Three months ..	263	0	0
English	261	0	0
Bars	260	5	0
Straits	265	2	6
Australian	261	12	6
Eastern	265	0	0
Banca	263	15	0
Off.aver.cash, Aug.	258	12	8½
Do., 3 mths., Aug.	258	6	6¾
Do.,Sttlmt. Aug.	258	13	0
Aver. spot., Aug.	258	13	0

SPELTER.

	£	s.	d.
Ordinary	37	3	9
Remelted	37	0	0
Hard	31	5	0
Electro 99.9 ..	41	10	0
English	37	12	6
India	32	0	0
Zinc dust	43	0	0
Zinc ashes	14	10	0
Off. aver., Aug.	36	9	1⅛
Aver., spot, Aug.	36	13	9

LEAD.

	£	s.	d.
Soft foreign ppt.	38	16	3
English	40	0	0
Off. average, Aug.	37	8	4½
Average spot, Aug.	38	3	9

ZINC SHEETS, &c.

	£	s.	d.
Zinc sheets, English	43	10	0
Do. V.M. ex whf.	43	0	0
Rods	49	0	0
Roller plates ..	42	0	0
Battery plates ..	42	0	0

ANTIMONY.

	£	s.	d.
Special brands, Eng.	74	10	0
Chinese	66	10	0
Crude	57	0	0

QUICKSILVER.

	£	s.	d.
Quicksilver ..	13	10	0

FERRO-ALLOYS AND STEEL-MAKING METALS.

Ferro silicon
45/50% 12 10 0
75% 21 5 0
Ferro-vanadium—
35/40% .. .. 16/- lb. va.
Ferro-molybdenum—
70/75% c. free .. 7/- lb.
Ferro-titanium—
23/25% carbonless 1/1 lb.
Ferro-phosphorus, 20/25%, £22 0 0
Ferro-tungsten—
80/85%,c.fr. 1/8 to 1/8½ lb.
Tungsten metal powder—
98/99% 1/11 to 1/11½lb.
Ferro-chrome—
4/6% car. .. £23 7 6
6/8% car. .. £23 0 0
8/10% car. .. £22 10 0
Ferro-chrome—
Max. 2% car. £40 0 0
Max. 1% car. £52 0 0
Max.0.70%car. £56 10 0
70%, carbonless 1/5 lb.
Nickel—99%,
cubes or pellets £170 to £175
Cobalt metal—98/99% 10/- lb.
Aluminium 98/99% £118
Metallic Chromium—
96/98% .. 3/9 lb.
Ferro-manganese (net)—
76/80%, loose £15 7 6
76/80%, packed £16 7 6
76/80%, export £15 5 0
Metallic manganese—
94/96%, carbonless 2/- lb.
Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

Finished bars, 14% tungsten .. s. 2 d. 6
Finished bars, 18% tungsten .. 3 0
Per lb. net, d/d buyers' works.
Extras—
Rounds and squares 3 in. and over .. 4d.lb.
Rounds and squares under ½ in. to ¼ in. 3d. lb.
Do. under ¼in. to ⅜ in. .. .. 1/- lb.
Flats, ½in. × ¼in. to under 1 in. × ⅜ in. 3d. lb.
Do. under ½in. × ¼in. 1/- lb
Bevels of approved sizes and sections 6d. lb.
Bars cut to length 10% extra

Scrap from high-speed tool steel—
Scrap pieces .. .. 3d.
Turnings and swarf 1d.
Per lb. net, d/d steel makers' works.

SCRAP.

South Wales—	£	s.	d.	£	s.	d.
Hvy. steel	3	6	0	to 3	7	6
Bundled steel & shrngs.	3	1	0	to 3	5	0
Mixed iron & steel	2	10	0	to 3	2	0
Heavy cast iron	3	5	0	to 3	7	6
Good machinery for foundries	3	10	0	to 3	12	6

Cleveland—	£	s.	d.
Heavy steel ..	2	17	6
Steel turnings ..	2	3	0
Cast iron borings	2	0	0
Heavy forge ..	4	0	0
Bushelled scrap	3	4	0
Cast-iron scrap	3	7	6 to 3 11 0

Lancashire—	£	s.	d.	£	s.	d.
Cast-iron scrap ..	3	10	0	to 3	12	6
Heavy wrought	3	10	0			
Steel turnings ..	2	5	0			

London — Merchants' buying prices delivered yard.

	£	s.	d.
Copper (clean)..	53	0	0
Brass (clean) ..	40	0	0
Lead (less usual draft)	33	10	0
Tea lead ..	29	10	0
Zinc	24	0	0
New aluminium cuttings ..	92	0	0
Braziery copper	48	0	0
Gunmetal ..	48	0	0
Hollow pewter	175	0	0
Shaped black pewter ..	128	0	0

PIG-IRON.

(*f.o.t. unless otherwise stated*).

N.E. Coast—	
Foundry No. 1 ..	72/-
Foundry No. 3 ..	68/-
Foundry No. 4 ..	67/-
Forge No. 4	66/6
Hematite No. 1 ..	75/6
Hematite M/Nos. ..	75/-
N.W. Coast—	
Hem. M/Nos. d/d Glas.	85/6
,, d/d Birm.	95/-
Midlands—	
Staffs. common* ..	102/-
,, No. 4 forge ..	67/6
,, No. 3 foundry	69/-
Shrops. basic	70/-
,, Cold blast, ord.*	190/-
,, ,, roll iron* ..	195/-
* d/d Birmingham.	
Northants forge	57/6
,, fdry No. 3 ..	62/6
Derbyshire forge ..	59/6
,, fdry. No. 3 ..	67/6
,, basic	67/6
Scotland—	
Foundry No. 1 ..	85/-
,, No. 3 ..	80/-
Hem. M/Nos.	81/6
Sheffield (d/d district)—	
Derby forge	63/3
,, fdry. No. 3 ..	71/6
Lincs. forge	69/-
,, fdry. No. 3 ..	72/-
E.C. hematite	85/-
W.C. hematite ..	88/-
Lincs. (at furnaces)—	
Forge No. 4	63/-
Foundry No. 3.. ..	66/-
Basic	63/6
Lancashire (d/d eq. Man.)—	
Derby forge	67/-
,, fdry. No. 3 ..	75/-
Northants foundry No. 3	75/6
Dalzell, No. 3	110/-
Summerlee, No. 3 ..	98/-
Glengarnock, No. 3 ..	98/-
Gartsherrie, No. 3 ..	98/-
Monkland No. 3	98/-
Coltness, No. 3	98/-
Shotts, No. 3	98/-

FINISHED IRON & STEEL.

Usual District deliveries for iron; delivered consumers' station for steel.

Iron—	£	s.	d.	£	s.	d.
Bars(cr.)	11	12	6 to	12	10	0
Angles				12	7	6
Tees to 3 united ins.				13	2	6
Nut and bolt ..				11	7	6
Hoops	14	0	0 to	15	0	0
Marked bars (Staffs.) f.o.t. ..				14	10	0
Gas strip				12	15	0
Bolts and nuts ⅜ in. × 4 in. ..				16	15	0

Steel—	£	s.	d.	£	s.	d.
Ship plates	8	0	0 to	8	15	0
Boiler plts.	£11	10	to	13	0	0
Chequer plts.	£9	15	to	10	5	0
Angles	£7	15	0 to	8	5	0
Tees	£9	0	0 to	9	5	0
Channels	£7	7	6 to	7	17	6
Joists	£7	15	0 to	8	5	0
Rounds and Squares 3 in. to 5½ ins. ..				9	0	0
Rounds under 3 in. to ⅜ in.				8	15	0
Flats, over 5 in. wide and up ..				9	10	0
Flats, 5in. to 1½in.				8	10	0
Rails, heavy ..				8	10	0
Fishplates				12	10	0
Hoops (Staffs.)	£11	0	0 to	11	10	0
Black sheets, 24g.				11	5	0
Galv. cor. sheets, 24g.				16	5	0
Galv. fencing wire 8g. plain				14	0	0
Billets,soft	6	10	0 to	7	15	0
Billets, hard ..		9	0	0		
Sheet bars	6	7	6 to	6	15	0
Tin bars d/d	6	7	6 to	6	15	0

PHOSPHOR BRONZE.

	Per lb.	basis.
Strip	1	3
Sheet to w.g.	1	3¼
Wire	1	3¾
Rods	1	3
Tubes	1	8
Castings	1	2

Delivery 3 cwt. free
10% phos. cop. £40 above B.S.
15% phos. cop. £50 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	9d. to 1/3
Rolled—	
To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3¼ to 1/9¼
To 15 in. wide	1/3½ to 1/9½
To 18 in. wide	1/4 to 1/10
To 21 in. wide	1/4½ to 1/10½
To 25 in. wide	1/5 to 1/11
Ingots for spoons and forks ..	9d. to 1/5½
Ingots rolled to spoon size ..	1/- to 1/8½
Wire round—	
3/0 to 72/- G.	1/6½ to 2/1½

with extras according to gauge

AMERICAN IRON & STEEL.

At Pittsburgh unless otherwise stated.

	Dollars
No. 2X foundry, Phila.	21.76
No. 2 foundry, Valley	20.26
No. 2 foundry, Birm.	18.50
Basic	19.76
Bessemer	20.76
Malleable	20.26
Grey forge	19.76
Ferro-mang. 80% d/d	115.00
Bess. rails, h'y, at mill	43.00
O.-h. rails, h'y at mill	43.00
Bess billets	35.00
O.-h. billets	35.00
O.-h. sheet bars ..	35.00
Wire rods	45.00
	Cents.
Iron bars, Phila. ..	2.12
Steel bars	1.90
Tank plates	1.80
Beams, etc.	1.90
Skelp, grooved steel ..	1.90
Skelp, sheared steel ..	1.90
Steel hoops	2.40
Sheets, black, No. 28..	3.15
Sheets, galv., No. 28 ..	4.20
Sheets, blue an'l'd, 9 & 10	2.25
Wire nails	2.65
Plain wire	2.50
Barbed wire, galv. ..	3.35
Tinplate, 100 lb. box	£5.50

COKE (at ovens).

Welsh foundry	37/6
,, furnace ..	27/6
Durham & North.	
,, foundry ..	35/-
,, furnace ..	15/-
Other Districts, foundry	35/-
,, ,, furnace (Basis)	13/6

TINPLATES.

f.o.b. Bristol Channel ports.

I.C. Cokes,	20×14, box	19/4½
,,	28×20, ,,	38/9
,,	20×10, ,,	28/3
,,	18¾×14, ,,	20/3
C.W.	20×14, ,,	17/9
,,	28×20, ,,	35/9
,,	20×10,	24/9
,,	18¾×14, ,,	18/3

Terneplates 28×20, 35/6 per box basis f.o.b.

SWEDISH IRON.

Bars, hammered	£19/0 to £20/0
Rolled Ord.	£16/0/0 to£16/10/0
Nail rods	£16 5 0 to £16 15 0
Keg. steel nom.	£33 to £35
Faggot steel nom.	£22 to £25
Blooms, according to quality	£10 to £14

Pig-iron £6 15 0 to £7 0 0 all f.o.b. Gothenburg.

TUBES.

Up to and incl. 6 in.

Gas .. 55% } Tube prices
Water .. 50% } are
Steam .. 45% } now free.

DAILY FLUCTUATIONS.

Standard Copper (Cash).

	£	s.	d.		
Sept. 10	61	17	6	dec.	2/6
,, 11	62	2	6	inc.	5/-
,, 14	62	7	6	,,	5/-
,, 15	62	12	6	,,	5/-
,, 16	62	10	0	dec.	2/6

Electrolytic Copper.

	£	s.	d.		
Sept. 10	67	15	0	inc.	5/-
,, 11	67	15	0	No change	
,, 14	68	5	0	inc.	10/-
,, 15	68	10	0	,,	15/-
,, 16	68	10	0	No change	

Standard Tin (cash).

	£	s.	d.		
Sept. 10	255	10	0	inc.	17/6
,, 11	257	10	0	,,	40/-
,, 14	257	17	6	,,	7/6
,, 15	258	2	6	,,	5/-
,, 16	260	15	0	,,	52/6

Tin (English ingots).

	£	s.	d.		
Sept. 10	255	15	0	inc.	25/-
,, 11	257	15	0	,,	40/-
,, 14	258	0	0	,,	5/-
,, 15	258	5	0	,,	5/-
,, 16	261	0	0	,,	55/-

Zinc Sheets (English).

	£	s.	d.		
Sept. 10	43	10	0	No change	
,, 11	43	10	0	,,	,,
,, 14	43	10	0	,,	,,
,, 15	43	10	0	,,	,,
,, 16	43	10	0	,,	,,

Spelter (ordinary).

	£	s.	d.		
Sept. 10	36	18	9	No change	
,, 11	37	1	3	inc.	2/6
,, 14	37	1	3	No change	
,, 15	37	3	9	inc.	2/6
,, 16	37	3	9	No change	

Lead (English).

	£	s.	d.		
Sept. 10	39	10	0	No change	
,, 11	39	10	0	,,	,,
,, 14	39	10	0	,,	,,
,, 15	39	15	0	inc.	5/-
,, 16	40	0	0	,,	5/-

Belgium:—Production of Manufactured Iron and Steel.

Year.	Rails and sleepers.	Tyres and axles.	Thick plates and sheets.	Thin plates and sheets.	Merchant bars.	Shapes.	Joists.	Steel rods and hoops.	Steel forgings.	Other material.	Totals.
	Metric tons.	Metric tons.	Metric tons.	Metric tons.	Metric tons.	Metric tons.	Metric tons.	Metric tons.	Metric tons.	Metric tons.	Metric tons.
1890 ..	123,540	9,075	123,692		—	—	459,821	—	—	—	716,128
1891 ..	133,332	10,625	125,299		—	—	434,789	—	—	—	703,685
1892 ..	127,439	9,103	131,591		—	—	419,156	—	—	—	687,289
1893 ..	106,112	7,648	143,600		—	—	452,583	—	—	—	709,943
1894 ..	114,946	9,769	155,576		—	—	514,317	—	—	—	794,608
1895 ..	122,782	7,359	151,653		—	—	530,952	—	—	—	813,846
1896 ..	148,210	10,497	177,250		—	—	677,386	—	—	—	1,013,343
1897 ..	138,354	10,870	164,618		—	—	688,594	—	—	—	1,002,436
1898 ..	118,588	10,953	178,905		—	—	744,322	—	—	—	1,052,768
1899 ..	123,936	11,212	203,499		—	—	770,501	—	—	—	1,109,148
1900 ..	134,821	11,934	160,850		—	—	619,097	—	—	—	926,702
1901 ..	132,260	12,380	150,490		334,910	137,550	48,350	—	54,260	—	870,200
1902 ..	268,220	12,790	168,630		380,990	113,990	109,390	—	52,940	—	1,106,950
1903 ..	351,540	17,810	187,910		446,360	118,410	119,860	—	64,730	—	1,306,630
1904 ..	—	—	—	—	—	—	—	—	—	—	1,378,750
1905 ..	—	—	—	—	—	—	—	—	—	—	1,469,020
1906 ..	—	—	—	—	—	—	—	—	—	—	1,522,990
1907 ..	314,760	34,700	148,690	82,420	594,170	169,890	158,040	50,100	6,690	—	1,575,190
1908 ..	191,370	29,000	135,390	93,790	544,810	119,5 5	121,490	39,570	3,750	—	1,296,050
1909 ..	214,000	33,960	170,750	112,160	628,740	139,380	151,880	101,770	3,570	—	1,569,560
1910 ..	347,890	31,860	177,110	122,830	672,730	172,190	168,000	126,530	2,530	—	1,834,050
1911 ..	337.520	35,450	211,410	130,250	711,320	183,570	196,590	121,790	6,220	—	1,945,230
1912 ..	339,060	40,320	258,800	141,290	878,640	195,750	213,820	144,300	8,560	—	2,238,020
1913 ..	341,870	34,180	354,650		614,130	187,420	175,210	14,220	8,220	—	1,729,900
1914 ..	152,750	15,270	244,000		491,100	118,030	99,050	100,040	4,040	—	1,224,280
1915 ..	29,470	2,940	38,000		76,900	7,690	5,490	1,770	620	—	162,880
1916 ..	9,730	2,500	67,000		122,200	2,880	3,440	5,230	1,210	—	214,190
1917 ..	730	750	23,100		42,900	280	60	930	240	—	68,990
1918 ..	—	—	14,400		48,900	—	—	—	—	—	—
1919 ..	53,960	5,390	92,700		161,100	20,570	26,720	25,410	1,820	—	387,670
1920 ..	128,500	18,840	263,000		541,000	60,220	83,810	92,960	7,440	—	1,195,770
1921 ..	127,620	18,420	104,320	55,290	247,920	100,950	65,090	113,970	3,450	—	837,940
1922 ..	192,470	23,370	100,860	182,000	461,380	158,100	152,120	168,610	2,200	25,640	1,466,750
1923 ..	227,560	33,940	145,110	217,140	734,840	164,710	197,290	217,100	1,440	40,740	1,979,870

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